ADAH. Unnumbered stars
Spangle the wonderful mysterious vault
With things that look as if they would be suns;
So beautiful, unnumbered and endearing,
Not dazzling, and yet drawing us to them,—
They fill my eyes with tears.

* * * *

CAIN (*to* LUCIFER.) Thou hast shown me wonders; thou hast shown me
Mighty pre-Adamites who walked the earth
Of which ours is the wreck; thou hast pointed out
Myriads of starry worlds of which our own
Is the dim and remote companion, in
Infinity of life; thou hast shown me shadows
Of the existence with the dreaded name
Which my sire brought us—Death!

* * * *

ADAH (*again.*) Cain, that proud spirit who withdrew thee hence
Hath sadden'd thine still deeper. I had hoped
The promised wonders which thou hast beheld,—
Visions thou say'st of past and present worlds,—
Would have composed thy mind into the calm
Of a contented knowledge; but I see
Thy guide hath done thee evil.

BYRON.

SCIENTIFIC CERTAINTIES

OF

Planetary Life:

OR,

NEPTUNE'S LIGHT AS GREAT AS OURS,

WITH

VARIOUS OTHER HITHERTO UNCONSIDERED FACTS CONNECTED WITH THE RESIDENCE OF MORAL AGENTS IN THE WORLDS THAT SURROUND THE STARS.

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CONTENTS.

ERRATUM.

Page 129, line 10, *for* "implied" *read* "inferred."

PREFACE.

It is not perhaps generally known that by recent improvements in the telescope, we are able to see great numbers of the planets that revolve around the Fixed Stars.

The only question that can be raised respecting these planets is as to whether they are opaque and luminous, like Jupiter, or self-luminous like our Sun; and on this point, however strong the probability that there is to guide us, we have as yet no direct evidence.

The evidence, it is true, which we have of their being opaque is precisely the same as that which we have of Jupiter's being so, which is his revolving round a central body just as the planets which are known to be opaque, and his being

sufficiently near to a self-luminous centre to give him his light, without its being necessary for us to multiply causes, and to suppose any other source of light for him, except that obvious one. All this is true of these stellar planets also. But we must remember that even in Jupiter's case this is only probable evidence.

We know also that Jupiter's light, long after his disc had ceased to be visible, could still be seen in a six-foot reflector, as an extremely minute point, like some of these stellar planets, from a distance at which the sun of our system could be seen by the naked eye as a star of the first or second magnitude; we know this, because we know that Jupiter's diameter is but ten times less than the sun's, and that the light from each luminous point of his surface, although reflected light, cannot be so much less than that from each luminous point of the sun's surface as to make this effect impossible in a telescope that would magnify his light 6000 times. This will become still more evident from Part II. sect. 2. But we must not allow ourselves to

forget that the fact now mentioned yields likewise only indirect evidence:—that with our present knowledge, neither in the case of Jupiter nor in that of the binary and other multiple stars can anything less than a transit have the force of direct evidence.

The question therefore as to the opaque condition of the stellar planets that we see, merges for the present in the general one as to whether there are or are not opaque planets around the stars; but the fact of our seeing planets there at all—especially planets that are as likely to be opaque as Jupiter is—naturally contributes a large accession of probability for the solution of the latter question.

The object then of these pages is to explain more explicitly perhaps than has yet been done by others that the argument which makes it probable—the argument upon which it is generally believed—not only that the eight known planets of our system are inhabited, but also that the stars have opaque planetary systems like ours, is one drawn from analogy in its

strictest sense; and one wholly drawn from it—one wholly drawn from that kind of evidence which "is to us," as Bishop Butler truly says, "the rule of life;"—and further, with regard to the Fixed Stars, to indicate in detail all those known points of resemblance between our Sun and them which constitute in their case this analogy (Part I.); and with regard to the planets of our own system, to explain the groundlessness of all those suppositions which have been hitherto allowed to perplex, although not to obstruct, the natural inference flowing from the earth's acknowledged analogy to the other planets of our system. (Part II.)

Those who prefer to examine scientific questions without reference to their religious bearings, will not regret to learn that science alone solves wholly those before us (viz., that respecting the habitable condition of our planets and that respecting the solar condition of the stars);—and does this in so peremptory a manner as to leave no room whatever for the moral, metaphysical, and theological considerations which

it has lately been attempted to introduce into these questions. Those, on the other hand, who view the subject, as so many naturally do, with the deeper interest on account of its religious bearings, and who have been lately startled to find the ancient belief of the first Jewish converts (Heb. i. 2), if not of the whole primeval nation, as well as the articles of the Nicene and Athanasian Creeds founded upon it, boldly called in question upon these supposed "moral, metaphysical, and theological" grounds, will probably likewise learn with satisfaction, that scientific facts positively declare the physical impossibility of the suppositions employed to make the new doctrine appear plausible, and that they give an overwhelming force to the analogies upon which the old one seems to have been originally founded.

For the purpose just alluded to, an effort was made last year in an anonymous Essay, "Of the Plurality of Worlds," to make it appear that the planet third in order outwards from the centre of a solar system, is the only one of the planets of such a system that can ever possibly be inha-

bited by beings capable of knowing God, and that but very few, if any, of the Fixed Stars, except our sun, are likely to have opaque planets of any description. This extremely curious attempt is, perhaps, the first of the kind that has ever been publicly made; for that of Dr. Cullen, the Roman-catholic Archbishop, something to the same purpose a few years ago, seems to have been suppressed, either by the authority of his Church, as excess of zeal, or in consequence of his own discernment of its unsuitableness to the present advanced state of science in this country. The English Protestant Essay therefore being the only thing of the kind that has ever been attempted, is necessarily, for that reason more than for any other, the frequent subject of allusion in a Treatise, which had it not been for that Essay, would probably never have been written; and if these allusions are found to be exempt from the usual language of that indignation and impatience with which we naturally look upon any act of a learned and sagacious man, calculated to misguide or impede

the advancement of those who are less learned or less sagacious than himself, it is from no wish to disclaim this indignation that the expression of it finds no place here. Those who, while they acknowledge the evil done, experience this feeling less than others, do so from no very creditable cause; but those who express it less, may do so because they see less danger from the act than others see; and this is my case. The author of the Essay, probably under some delusion or mistaken hope of doing good, has, it is true, as every learned and skilful man has more or less the power of doing for a time, placed the drag upon the chariot-wheels of human progress; but happily the impediment in this case seems but to have given impetuosity to the onward course, and discontent is silenced by the gratifying probability, which starts up on every side, that the immediate result of this unhappy attempt will be rather to make people acquainted with the grounds of their belief in other worlds of moral beings, than to disturb it, and thus to accelerate rather than to retard our human progress,—

our onward course towards that more intimate and exact acquaintance with the works of the Almighty after which we all strive.

As to the arguments of this author to the effect that all astronomical research that tends to the extension of planetary life beyond the brute creation, favours the views of the Arians and Socinians, by necessitating, it is supposed, the sacrificial sufferings of an Uncreated Being in or for each of these moral worlds—a supposition attended, we are told, with grave and perplexing difficulties—as well as to the effect that such research is at variance both with the exclusive presence of brute fossils in all those portions of the lower strata of our own planet that have yet been examined, and with the ordinary known usages of an uneconomising Providence,—I abstain in this volume from all discussion of these matters,—confining myself solely to those astronomical facts and the analogies founded on them, that are thus declared to be incompatible with other facts equally well attested, and with other analogies equally strong.

It will be shown on a future occasion, if requisite, that there is none of this alleged incompatibility. It will be shown, if requisite, that neither geology, nor the course of nature, nor Revelation, nor any other department of our knowledge, is at variance with astronomical research; but it does not seem credible that any considerable portion of the reading public will ever need such explanations.

For instance:—

That there is nothing inconsistent with any form of the Christian Faith in our supposing that all the planets of all the stars are inhabited by intellectual, moral, and religious beings, and not, as this author supposes, by brutes only, is what almost any sincere Christian can prove for himself, provided he approach the subject with a *firm* belief, or if he fail in that, at least, argumenti causâ, with an unqualified philosophical assent that the Creator of all these worlds is *really* omnipotent—that He is really "mindful" even of each blade of grass without its costing Him exertion—that each tiny insect has really His "unique and

special care"—as much so as if it were an angel—exactly as much so as if He had nothing else to bestow care upon; and there must be, besides, a preliminary admission that beside much that we are permitted and intended to understand in these "unique" visitings, and in this "unique" care, there is necessarily much that we cannot and that we are not permitted to understand. Such a Christian—one who is neither a believer (like Paine) in degrees of omnipotence, nor a disbeliever (like Voltaire) in everything that is incomprehensible — will find no inconsistency either in the scientific or theological mysteries of existence, and will see but a poor solution of any of these mysteries in the assertion that his Maker's stupendous universe of radiant worlds is in all human probability a universe of brutes, —a universe in which there is but one very small world capable of anything like religion. "A belief in the Divine Government of other races of spiritual creatures beside the human race, and in Divine Ministrations committed to such beings, cannot," says the Essayist, "be connected with

our physical and astronomical views of the nature of the stars and the planets, without making a mixture altogether incongruous and incoherent; a mixture of what is material and what is spiritual, adverse alike to sound religion and to sound philosophy." — (Chap. xii. 19.) A universe of "creatures of the nature of corals and molluscs, saurians and iguanodons," "microscopic creatures with silicious coverings almost indestructible by heat," "sluggish monsters," some "watery," some "pulpy," others "glutinous," many "boneless;" countless worlds of brutes, (and such brutes!)—more congruous with sound religion and sound philosophy than countless worlds of moral agents for whom it is life and happiness to love their God! Well may we exclaim with the Essayist himself on another occasion, "Highly curious!" Who can wonder, however, that there should be some who receive such levity with indignation rather than with a smile? Who is there that does not feel how different this writer's "sound philosophy" and "sound religion" are from all that reason, or

Revelation, or science teaches us? In this great question let the humble Christian stand by his scientific facts. These are gifts from Him by whom they might have been withheld. Let him stand by his rational inferences. These are gifts also. Let him not seek to help his understanding by denying such things, and by rudely pulling as it were into ruins at his feet, the universe appointed for his instruction. Let us say what we may of it, this is but one form of impiety. "Truths physical," it is well observed by Sir David Brewster, "have an origin as divine as truths religious." Whatever is incomprehensible (as much undoubtedly is) let it remain so. It ought not to be incomprehensible to us that our Maker should be able to do incomprehensible things. Let it remain among our researches as a residual phenomenon (we have many such), to be comprehensible later, if it is not so now; but let it not be denied merely because it is incomprehensible. In the case in question, however, what is there that is incomprehensible? The Essayist has stated

nothing. His own theological theory—or rather this strange brute hypothesis of his alone is so.

As to what he speaks of as his geological difficulty, we concede to him the remarkable fact that no human remains have been yet discovered of a date anterior to the Creation which Moses has recorded, and that we have therefore as yet no evidence of this kind that this little globe of ours had been previously inhabited by moral creatures; but we deny that this affords any reasonable grounds, or any imaginable grounds at all, for the preposterous supposition that in all human probability, therefore, none but brute animals of various orders inhabit, at this hour, the myriads and myriads of other worlds in the universe. Even if our geological evidence were positive instead of negative—and demonstrative instead of probable,—even if we had ransacked every portion of every stratum of our earth to the very innermost without finding human remains to antedate our Scriptures, while brute remains presented themselves in every portion of every stratum, and with undisputed evidence

of its being physically impossible for such strata to have resulted from the operation of the Mosaic incidents, we could not even then follow this writer to his wild conclusion. To say nothing of the other very obvious explanations which would in such a case suggest themselves, the sincere Christian, looking forward to a resurrection of the body in his own case, would read in the immense fact now supposed, a grander lesson than that this earth is the centre of a whole universe of brutes. Yet we have supposed a stronger case for the Essayist than he himself pretends to.

Finally, there cannot be many who will think that because of all the millions and millions of thistle seeds that floated over our fields last year, it is not probable that more than a very small number—say ten thousand—have taken root and grown to maturity, it therefore follows that of all the millions and millions of stars, launched into space, it is not probable that more than three or four have "produced" opaque planets, or probable that, if opaque planets sur-

rounded all those stars, of all the opaque planets thus pervading space, more than three or four are at all likely to have any other but brute animals inhabiting them. — (Chapter xi. 11.) Even if there were no confusion and inaccuracy in such dialectics as these,—even if ten thousand successful in one case logically implied only three or four successful in the other, are we to take no account of the very close relation in which the vegetable and the brute creations manifestly stand to man? Are we to draw no distinction between those acts of the Almighty over which man is allowed control and those over which he is allowed none—no distinction between the unfailing sunrise and the failing plant? Is it, after all, to be supposed that it is from any want of thistle-making or fish-making powers, that every thistle seed and every fish-spawn is not productive? Does it, after all, require so much discernment to see that the waste of these things has a reference to man, and that the supposed waste of stars and planets could have none? How many thistle-seeds would fail if

man took care of them? How many stars or planets could his care save from failure? Let us hope that there are not many persons incapable of making such distinctions. Let us hope that there are many who are convinced that the carelessness (shall we use that word?) as well as the carefulness of God are alike intended and alike adapted to exercise the moral and intellectual faculties of man, and that to assume this want of care where man's care could effect nothing (such as in wasted suns and wasted planets) is gratuitous assumption. Is it not much worse than merely gratuitous? But even if our theology is of so low an order, do not the "possible thistles" and the "possible planets" of the Essay present to our convictions a very considerable number of actual ones—a much greater number of actual thistles and actual planets than the Essayist could have intended that his illustration should have furnished?

I repeat, that I much doubt whether the impression produced by the Essay alluded to will render explanations or discussions upon such

matters necessary. At all events, for the present I offer none, but proceed at once to examine upon what astronomical grounds this Essayist pretends that there is no analogy for believing that the stellar planets are opaque bodies, although there is for believing all the exterior planets of our own system to be so, nor any analogy for believing that there are opaque stellar planets generally around the stars; also upon what astronomical grounds he pretends that moral agents could not subsist upon any of the planets of any system, except upon that which is the third in order outwards from the sun of each system.

What there is, upon these points, scientifically certain in our belief of Planetary Life, is here placed before the public; and the more important portions of this matter now appear for the first time.

Clevedon, Somersetshire,
December, 1854.

SCIENTIFIC CERTAINTIES

OF

Planetary Life.

INTRODUCTION.

We are not called upon to prove either the long standing or the reality of the popular conviction respecting the presence of intellectual creatures with material bodies, like human beings, in the orbs of heaven. It is admitted on all hands that this is and has long been the familiar and established view of all earnest minds, even of those who are without evidence of any definite kind connected with it. The only question that can arise respecting this involuntary prepossession of mankind—the only question that it at all now concerns us to consider is, as to whether scientific research corroborates it or contradicts it. That scientific research, however, corroborates it, is at once

proved by the fact that all the most profound astronomers of modern times recognise the perfect reasonableness of the belief, and the extreme probability of its truth, while no astronomer at any period has ever held the contrary opinion. Research, indeed, makes a distinction unknown to the uninstructed. It is not so much to the stars as to the planets around each of them, that the astronomer assigns the inhabitants, and not so much to the secondary planets as to the primaries. But the belief of all is the same. Life, intelligence, and worship belong to every individual star. "For what purpose are we to suppose such magnificent bodies scattered through the abyss of space?" asks the exact and enlightened Herschel of our own day. * * * "He must have studied astronomy to little purpose who can suppose man to be the only object of his Creator's care, or who does not see in the vast and wonderful apparatus around us provision for other races of animated beings. * * * These doubtless, then, are themselves suns." "Divided from our firmament and from each other," says the eloquent Dr. Nichol, "by measureless intervals, numerous

firmaments, glorious as ours, float through immensity, doubtless forming one stupendous system, bound together by fine relationships. * * * One of these, perhaps the most brilliant, is in the constellation Hercules. After all, how easy the belief to its in-dwellers, that a mass thus surpassingly gorgeous, is infinite. What wonder although the inhabitant of a planet revolving around one of its central suns should have mistaken his own magnificent heavens for the universe, and have needed the distant and dim vision of our firmament, appearing to his telescope as a starry speck, to remove the veil from his mind, and give him juster notions of the Majesty of Creation."

Let us, then, examine what grounds there are for this unanimity of the astronomers. No less than eight separate questions may be enumerated in connexion with it—viz.,

1. Are all the fixed stars (or most of them) inhabited?

2. Are their planetary systems inhabited?

3. Is our sun inhabited?

4. Are all the eight primaries of our system inhabited?

5. Are the comets inhabited?
6. Are the planetoids inhabited?
7. Are secondary planets inhabited?
8. Is our own secondary inhabited?

The first of these questions depends upon the third, and the seventh upon the eighth, while the fifth depends to a very great extent upon the same probabilities or improbabilities as the sixth. These six of the questions, however, we propose to put aside for the present, as referring to bodies that bear but a partial analogy to the only one known by experience to be inhabited, and as therefore requiring arguments of a totally different nature from that analogy, by the aid of which alone, to the exclusion of all other considerations, it is proposed to conduct the following investigations.

The second of the above questions depends upon exactly the same pure analogy as the fourth, and is therefore true in whatever sense, and to whatever extent, the fourth is true, provided it can be shown that the stars have opaque planetary systems like ours. If our telescope or our reason teaches us that all the fixed stars, or most of them, have such systems, it

would be little short of absurd (it is admitted on all hands) to assume that none of these systems, or but very few of them, were inhabited as ours is. The point, therefore, which needs discussion with regard to Question 2, is not as to whether the opaque planets of the stars are inhabited by creatures like ourselves in intellectual and moral faculties, but as to whether the points of resemblance which are found to exist between the stars and our sun are numerous enough, in the absence of any known difference, to justify the astronomers in believing that they also resemble him in the opacity of their large luminous planets recently discovered, whose light reaches us even here (so much larger are these than our own luminous Jupiter or Saturn), or at least in having smaller opaque luminous planets round them, which on account of the distance we cannot yet see at all.

Thus the strictly analogical portion of this investigation becomes narrowed to two questions,—viz.

I. Can we detect through the scientific discoveries of modern times, any such resemblance between the other fixed stars and our sun as to

render it at all likely—more likely we mean than unlikely—upon analogical principles that they may resemble him also in having opaque planetary systems such as he has?

II. Can we detect by this same light of science any such resemblance between the other seven primary planets of our system and the earth, as to render it at all probable that they may perhaps likewise resemble the earth in having inhabitants capable of knowing God;—which, after all, are the only sort of inhabitants whose existence can create much interest, or be said to be that intended in the general impression of mankind?

PART I.

THE STELLAR PLANETS.

The probability is uncontested that if the fixed stars have opaque planetary systems, these systems are much in the same predicament as ours is with respect to inhabitants. The main question, therefore, as far as science is concerned, respecting the extent of extra-terrene life throughout the universe, depends upon the probability or improbability of the fixed stars having such systems; or, to state the point more explicitly, upon the proof or disproof of the fact, first, that our sun is one of the fixed stars, and, secondly, that there is no such known kind of difference between any two of the fixed stars as to make it probable that one of the two has opaque planets and the other not. If these two points be fully established, it is admitted on all hands that it is in the highest degree probable, from analogy,

that all the fixed stars, without any exception that we can indicate, have these opaque planets, and that therefore at least *some* portion of each planetary arrangement contains the inhabitants in question; which at once presents us with innumerable worlds,—more, infinitely more, than even the popular belief originally extended to.

What then are the reasons for supposing our sun to be one of the fixed stars? Whatever establishes this fact, whatever establishes the stellar nature of our sun, establishes with equal force the solar nature of the stars, and nothing less than the proved unfitness of any given star can in that case constitute it an exception to this general analogy. In what points then, in what number and kind of points is the likeness between him and them known to exist? These we must fully appreciate before we suppose the likeness to extend to points in which we do not know that it exists.

There are but few particulars that can be *seen* that are common to all the fixed stars. In these, however, the stars are seen to be like each other. They are chiefly three—1. The independence of their light. 2. Their insulation in

space. 3. The permanence of these two properties. Such are perhaps the only three of the characteristics as yet known to be universal which can be said to be seen and not inferred.

The *inferred* characteristics of all the stars, those in which they are unanimously inferred to be all like each other, are more numerous. They are the ten following:—1. Force of gravity. 2. Elementary materials. 3. Their great (or solar) mass. 4. Periodical regularity. 5. Spherical shape. 6. Brightness. 7. Heat. 8. Density. 9. Rotation on their axis. 10. Their origin. Unless we have special proof to the contrary, in any given case, it is inferred that all these ten properties of the stars are the same in all of them.

The third class of these stellar characteristics are such as belong to individual stars, and are some of them inferred, some of them seen, but not all of them such as could be universally present, nor any of them such as are yet universally inferred to be so. Of these we may enumerate the following seven, as being the only ones yet known that are capable of being united in one and the same star. 1. Their dark spots. 2. Their

orbitual revolutions. 3. Their being grouped. 4. The white colour of their light. 5. Their central position to the orbitual revolutions of other bodies. 6. The elliptical orbits of their circumrevolving bodies. 7. Their position in regions where opaque masses are known to be in periodic movement. These are known to be the individual characteristics of many if not of all—as the former two classes are known to be universal characteristics of all the fixed stars.

Although it is true that a body is not less evidently one of the fixed stars, either on account of its having or on account of its not having these last seven peculiarities, or any of them, the stellar nature being mainly determined by the stellar properties, which are universal, yet when we find that a given body is not only like the fixed stars in all their universal, but in most of their so-called individual properties—not only like all of them in the properties that are in all, but like portions of them in such peculiar properties as are yet only known to extend to portions—it must be admitted that, when any given body is like an immense number of other bodies to such an extent as this, the force of analogy

is carried to the highest degree to which the force of analogy can be carried in any case; and this is true of our sun and the rest of the fixed stars. He is like them, and they like him, not only in their universal attributes, but in all such partial or individual peculiarities as are not incompatible with one another.

A few words explanatory of each of the above points of resemblance between the stars and our sun are subjoined, it being merely premised that it is as proofs of this resemblance that they are adduced, and not by any means as being in any intelligible way necessarily connected with planetary systems. They prove with singular evidence that one of the fixed stars is a sun, and that all the fixed stars are, with wonderful exactness, like one another. That is almost all they prove; but that is abundant for our purpose. It is the ordinary principles of reason that teach us that, this being the case, it is in the highest degree probable that all the fixed stars have opaque planets.

Of the universal characteristics of the fixed stars:

I. Of those that are seen:

1. *The independence of their light.* To judge

of the extent to which this circumstance augments the likeness that otherwise exists between the stars and our sun, we need only reflect upon the way in which our opinion of this likeness would infallibly be affected, if it were ascertained that the stars shone with borrowed light. This would, it is true, be no ground for supposing that they had not planetary systems, for we know that opaque bodies can have these as well as those that are not opaque. It is not pretended that even their being known to be self-luminous is ground for supposing that they have these systems; but their being self-luminous proves them to be like our sun,—the only question just now before us; and this is important, for the dissimilarity between an opaque fixed star and a self-luminous one like our sun, would greatly detract from the analogy here indicated.

It is necessary, before we proceed any further, to examine a criticism offered upon their similarity in this respect by a recent essayist of considerable distinction; and this is the more necessary as the criticism, if just, applies with equal force to all the other properties in which the sun and stars resemble one another, the

result of it being that a sort of formula is proposed as a test of likeness, calculated, it is believed by its author, to give general satisfaction in the discussion of this and all the other properties that are in common between our sun and the rest of those orbs that are its companions in our firmament.

The essentials of the test thus proposed are:

1. That the property or nature in which the stars are like the sun should not be found in objects that are unlike the sun.

2. That some other property attributed to the sun and stars be deducible, as a necessary or very probable consequence, from this one item of likeness alone, without reference to any other.

3. That we should be able to infer from it alone, that a planetary system must necessarily accompany all bodies invested with this quality or nature—in other words, that there is a necessary connexion between this property and such a system.

4. That the one point of likeness in question should be strong enough to establish, of itself alone, the analogy sought for.

In the absence of these conditions it is suggested that there can be no analogy.

The mere statement of this fourfold test in language exempt from equivocation is perhaps sufficient to show that according to such a test of likeness, no such thing as analogy could exist upon any subject. The fact is that not one of the conditions proposed as essential is ever required. But the unfitness of the test will become more apparent if we show how it acts when applied by its author to the independence of light, common to both star and sun; and in doing so we shall take the liberty of freeing some of the original expressions from a vagueness evidently unintentional on the part of the author.

The stars, it is said, are like the sun in this, that they shine with an independent light—not with a borrowed light, as the planets shine. In this, however, the stars resemble not only the sun, but meteors, glowworms, and comets' tails, for these shine also with original light. This likeness then amounts to nothing, for who would speak of our sun as being like a glowworm or comet's tail merely because their light is of the

same nature? The stars then being granted to be like the sun in the independence of their light, our next question is—does it follow from this that they are of exactly the same size and weight (*i.e.*, of the same density) as he is?—or is it not much more probable, in the absence of all evidence of their being so, that they are a great deal larger, and of exactly the same weight as our sun, notwithstanding that remarkable similarity to him in the independence of their light?—for they might be (200 millions, diameter of the earth's orbit × 6000, telescopic power) considerably upwards of a million times larger than the sun, and only of the same weight as he is, yet, in consequence of their distance, seem to us mere points of light, as they do now. And let not this surprise us, for if they were still a great deal larger than this, we should lose sight of them altogether. If Sirius, for instance, were diffused (without increase of weight) through a sphere equal in diameter to the remotest limits of space that have yet been reached by the telescope, it would not be seen at all; as is evident by this, that telescopic space has no discoverable finitude, and the light emitted from

so diffused a body would be itself so infinitely diffused, and consequently attenuated, as to be completely invisible. If Sirius were in this diffused condition, such a circumstance, although it would render him invisible, would not, mechanically speaking, prevent his having planets revolving around him; for, as we have said, the attraction of his whole mass, in whatever state of spherical diffusion, will be the same as if it were collected at the centre. But such a state of diffusion will make him so unlike our sun as much to break the force of the presumption that he must have planets because our sun has. If the luminous matter of the stars gradually cools, grows dark, and solidifies, such diffusion would imply that the time of solidification is not yet begun in such a star; and therefore that the solid planets which accompany the central luminous body are not yet brought into being. In Sirius, indeed, as he now is—a star of the first magnitude—we may assume that the solidification has begun, and not only begun, but already made considerable progress. He is, therefore, one of those stars of which we may safely conclude that they are not much above one million

times more dilated in their substance than our sun is.

If any person is not satisfied with this account of the degree of resemblance in density between the fixed stars and the sun—as shown by the fact of their being all self-luminous—but would make the likeness greater than this, and suppose this immense dilatation of the stellar substance improbable merely because, like the solar substance, it is self-luminous, we have only to say that the proof that this immense dilatation is improbable lies upon him. Such a resemblance, in point of density or dilatation, as we have supposed, is all that the fact suggests—all that we can infer from their being self-luminous. That the stars are independent luminaries we see; but as to whether they are as compact as the sun, or globes one million or ten million times more diffused, many of them perhaps attenuated to invisibility—we have no means whatever of knowing this, and, in the mere fact of all being self-luminous, no grounds whatever of a rational probability respecting it; and to assume not only that stars may not be in such a diffused state as to be invisible, but to assume that beside those

condensed enough to be visible, there are also condensed bodies which are opaque and invisible, revolving round the others in permanent orbits which require special mechanical conditions; and to suppose all this (as has been so fully explained) not because we see the stars like the sun in the nature of their light, a fact which admits of no such inference, nor because we look upon this, when combined with several other remarkable points of likeness as constituting grounds for analogy, for there are no other such points of likeness to combine with it (all which would be perhaps not unnatural, if there were the materials of such reasoning), but to do so confessedly and evidently from no other motive than that of a mere wanton guess about inhabitants living somewhere upon other dark bodies beside the earth, just as if we were to conjecture the future discovery of a great city like Lonlon in 90° north latitude, and now assumed in those regions a large population and an extensive trade as things highly probable, merely to give probability to the existence of such a city, this is a hypothetical procedure which it seems strange that we should have to combat at the pre-

sent stage of the history of science, and in dealing with those who well know that the sun and the stars being self-luminous is no good reason for supposing that the stars are not in a much more diffused condition than the sun;—who know that it is much more probable that they are so, although we can assign no reason for thinking so, and that notwithstanding the mechanical possibility above alluded to, it is much more probable that planets would not revolve round such rare suns, but plunge at once into their attenuated luminosities, ploughing away in spiral paths right through the body of the star to its condensing centre.

But further:—The stars, it may be urged, are like the sun in being self-luminous. To this we reply, that we know this only of those stars in which the very phenomenon which proves their being self-luminous proves also that they are unlike the sun in being at a much greater distance from us than the sun. Add to which, their being self-luminous is not necessarily connected with the existence of planets, still less of inhabitants of planets, in any intelligible manner: a comet's tail we know has neither. The

resemblance, therefore, so far as it bears upon the question of analogy or corroboration, and so far as it results from self-luminousness, is confined to one single point, in the highest degree ambiguous and inconclusive, and any attempt to corroborate other points of resemblance by this, or by any one other solitary point of resemblance—any argument, in short, drawn from a single fact, has little claim to be termed an argument from analogy.

It is evident then, from this practical illustration of the test in question, that it is totally incompetent to its task, because totally subversive of all analogical reasoning. Analogies result from a preponderance of resembling points (not from one point, or two, or ten thousand), and these are either facts, or are derived from other analogies, and are then of the same value, in argument, as facts. Often a mere likeness in a most ambiguous and inconclusive point, when unopposed by any dissimilarity, constitutes an analogy of strength sufficient to determine the conduct of the most sagacious men on the most momentous occasions. But our question in this place is not as to the strength of the analogy, nor as to

whether there is any analogy at all between star and sun; but simply as to what are the resembling points between them; and no one denies that self-luminousness is one of these.

2. *The insulation of the stars in space.*—If, while our sun occupied his present isolated position, the rest of the fixed stars were not isolated, but were, on the contrary, in contact with one another, either in strings or in clusters;—or, although not in actual contact, yet in such close proximity to one another as to preclude all possibility of there being opaque planets revolving round them, there would in such a fact have been the sort of difference calculated to diminish considerably the impression now so generally felt, as to the analogy between them and our sun. This insulation, therefore, of the stars in space, where, as far as we know, a contrary arrangement was so possible, cannot fail to strike an impartial observer as a remarkable point of resemblance, as well as one of considerable importance. Nothing, however, can be clearer to the eye—nothing is more universally admitted by the learned, than it is that there is space enough between the stars,—even between those

that appear to the telescope the nearest to each other,—to admit of each of them having a planetary arrangement of some kind around it, and that in this respect our sun and they are like each other. From the stars of first magnitude to those of second magnitude, there is this space; from those of second to those of third, &c.; also from the stars of the first magnitude to our sun, from one star of first magnitude to another, and from the minutest star to its nearest neighbour. Our sun is upwards of twenty *million million* miles from any other star; and of the great majority of stars, there are no two known to be at a less distance than that from one another. No one supposes that these immense distances are accidental. How can it be doubted then, that it is in conformity to his stellar nature that our sun is thus isolated? or, which is but the same thing, that it is in conformity to a solar nature, that the fixed stars are placed at these great distances from one another?

The learned author of the recent work on this subject seems to think that some of the binary stars present us with exceptions to this general insulation of the stars in space, and with excep-

tions therefore to this point of general resemblance between our sun and the rest of the stellar orbs; at least so far an exception as to unfit these particular stars for planetary systems. But even if the calculations of the astronomers are exact in this respect, his misgivings are evidently without foundation. The constellation called *Alpha* Centauri, which appears to the naked eye as one large star, consists in reality of two unequal stars, the smaller one revolving round the larger, not quite equal (together) to the mass or weight of our sun, and at a distance from one another of about 2000 million miles —much less than the distance between Neptune and the sun—the smallest stellar interval yet suggested, and nearly 10,000 times less than that between any other two of the fixed stars.

Another of these double stars, which appears to this writer to offer an exception to the general sufficiency of space for planets around the stars, is that called 61 Cygni, the distance between the two stars composing which is estimated at nearly 60,000 millions of miles, a distance twenty times greater than that between Neptune and the sun. The learned author throws

out a doubt as to whether it would not be too complicated an undertaking for the Almighty to place inhabited planets with safety to the inhabitants around each of the two stars (supposing both to be self-luminous) in either of these constellations: "so complex a scheme," these are his expressions, "so impossible to arrange in a stable manner"! What can be the origin of such a doubt as this? Even the two closest of these stars—those in *Alpha* Centauri—could have each six opaque planets disposed as the six planetary places between Jupiter and Mercury inclusive, and yet have a vacant space of nearly 1000 million miles between the limits of the two systems. With such an interval neither sun could interfere with the other's action, even in their perihelion, more, or at least not much more, than the planets interfere with the sun's action on such occasions in our system.

In the tranquil revolutions of the planets around these two suns (for we here suppose, with the Essayist, neither to be opaque), there is nothing so perilous that need paralyze our faith in that unseen Hand by which the perturbations of our own system have been balanced against

each other in that fearful and wonderful manner, which has been described with so much force and beauty in Sir John Herschel's chapter on the subject. And if such revolutions are thus manifestly possible in *Alpha* Centauri, how much more so in 61 Cygni, where the two stars supposed to be both self-luminous are 30,000 times more distant from each other. That a quantity of nebulous matter left to itself should fail to produce a successful planetary system under such arduous and intricate circumstances we shall all admit; but what is the source of the assertion that on that account a planetary system under such circumstances is impossible? Nor is the above the only way in which the action of two suns so close together could be shown to be possible. If one is much smaller than the other, which is the case both in *Alpha* Centauri and in 61 Cygni, and, indeed, in most of the binary stars, the possibility of an arrangement is still more obvious; and if the opaque planets of such systems instead of revolving—some round one sun and some round the other, as above supposed, — are all revolving round the two suns, while these two suns are as

we see these stars revolving round each other, one is at a loss to see any difficulty at all in the construction of such a system,—at least one sees nothing in it more "complex" or more "impossible" than is to be found in every portion of our own most intricate system. And that it is perfectly and clearly possible for planetary systems of some kind to revolve around suns that are at no greater distance from one another than 2000 million miles, is all that is here required.

The probability of the thing it is not our present business to exhibit. Our proposition is, that the rest of the stars are as isolated as our sun; that they are sufficiently isolated from one another to admit of every star having a planetary system around it, and that in this respect they are all like our sun. It is evident that even the constellation *Alpha* Centauri—the two self-luminous stars (if such they are) least distant from each other that we know of—presents no exception. But what reason have we for thinking that the smaller star—the planet of this system —*is* self-luminous?

3. *The permanence of their insulation and of their light.*—No movement, at all adverse to in-

sulation, has ever been detected either in sun or star: nor is it pretended by any one that the light of either is more permanent than that of the other. Even the slight changes which are supposed to be constantly taking place in our sun's substance are inferred to be going on in the substance of the stars also, being in the latter, of course, for the most part imperceptible, even to our telescopes. A few stars indeed seem, in these changes, to have outstripped the rest. A few seem, in consequence (it is supposed) of these changes, to have lost some of their light, and one or two others to have become totally obscured during the last 2000 years, although no fresh star is recorded as having been gained to our starry host—a remarkable fact, which appears to suggest that whatever progress there may formerly have been (if it can be shown that there ever has been any) in the planetary systems of the universe and their suns, is, and has long been, at an end. But this loss of stars cannot be looked upon as constituting the smallest difference between our sun and those that remain. A similar stamp of permanence is now upon the light as well as upon the place both of him and them. It

is not now, it is true, in respect of light what it was before these stars vanished; but what it is on one it is on all. We learn from the lost suns that the other planetary systems that pervade the universe have an appointed termination. We are not without evidence, even in our own system, that this is also true of ours. Nor can we be very certain that our central star is as free from change as the great majority of the other stars around us: for, although we see but little indication of any change going on in the materials of which he is composed, yet how much of change, it has been truly said, may go on in any star without its being in any degree perceptible to the most exact astronomical scrutiny? We cannot, then, look upon him as either more or less permanent than the other stars in his light any more than in his insulation.

II. Of the unseen characteristics of the stars.

Of these we shall best speak collectively, inasmuch as they are to a great extent dependent on one another. There is not the slightest want of unanimity respecting them. From the general analogy that we can even *see* between the stars

and the sun, we infer that they all consist of that kind of *material* which we know to be attended with the phenomena of gravitation. It is evidently absurd to suppose a different kind of material for the composition of each star. It is therefore concluded that in their materials they all resemble our sun. As successive cases were observed, and those not a few, extending now to every region of the heavens, in which the phenomena of gravitation were evidently taking place before our eyes among the stars, this conclusion became more obstinate, and it is now in undisputed possession of our convictions. Even the theorists who differ most widely agree in this identity of the elementary composition. The *force of gravity*, however, must not be supposed to be the same in the case of every star. This naturally depends upon the *mass* or weight of each, and to judge of this we have but few data. One of these is the immense distances at which the stars are placed from one another. It is but natural to conclude that these distances are required by the corresponding force of gravity connected with each star; and finding these distances to be, for the most part, as great

between any two adjoining stars as they are between our sun and the stars nearest to him, it follows that the stars generally possess about the same attractive force as our sun, and therefore about the same mass. Another source of information and confirmatory of this, seems to lie in the binary stars; where we find the distances between the constituent stars less enormous than in any other groups supposed to be luminous, and the stars themselves accordingly rather less in weight (or mass) and attractive force than our sun. In all cases, however, since there is, as we have seen in a preceding page, the solar distance, we naturally conclude that there is the solar mass, and therefore the solar force of gravity connected with it—a sufficient mass and force to sustain a solar system. Whether any of the other stellar masses are greater than ours as well as less, we cannot tell, otherwise than by analogy. Since there are some less, we naturally conclude that there are some greater also; but as far as mere facts are concerned, we have not a single instance of a star having a heavier stellar mass than ours.

To what size these weights of matter are

dilated, or, in other words, what their *density* is, we have also no means whatever of determining except analogy. As far as sense goes, we *see* nothing, or next to nothing, that gives us the slightest clue to this; and the little that we do see gives us this clue only by an analogical application of it. We see for instance different degrees of brightness in the stars, and we know the stars to be at different distances from us. By universal consent it is thence inferred that the different degrees of brightness result from different amounts of distance, and not from different amounts of weight in the stars. But as we conclude from other considerations mentioned above, that there is some little difference in the amount of those solar weights, this circumstance may also to some little extent contribute to the different degrees of brightness caused by the differences of distance. An alteration, however, in the mere size of the star without reference to its mass could alter nothing in the degree of its brightness; for in proportion as its size were enlarged, its massiveness or density would be diminished, and consequently the luminous power of each square foot of its surface be diminished

also, although the sum total of these luminous square feet would be increased. Guided then by these reflections and by analogy, we have no alternative but to conclude (for from analogy we must not deviate without warrant) that all the stars have most probably the same density.

One ingenious speculator indeed has been found who, in his fruitless efforts to discover traces of unequal density in the stars—a supposition requisite for his theory—suggests that the different colours in the constituents of most of the binary stars result most probably from different degrees of density in those stars; and that, in the cases of some other stars, the unequal heat supposable is most probably attended with unequal density.

As to the first of these suggestions, his meaning seems to be that a certain colour indicates a certain density of the star's atmosphere, and therefore a corresponding density in the more solid substance of the star, since the density of an atmosphere is always in proportion to that of the nucleus it surrounds.

Now, if this suggestion applied at all, it would do so with a very different effect upon

the argument from that intended. If it applied at all, it would only, or at least mainly, apply to the smaller star of each pair, as the larger is generally of the same colour as the other stars, and being thus restricted, two remarkable consequences would have resulted from the truth of it. One is, that the only bodies to which it would have applied, would have been some which, there is good reason to suspect will turn out not to be self-luminous stars at all, but opaque planets, and which, even if they are self-luminous stars, are certainly none of those unequivocal ones which people generally mean when they speak of the stars as being like our sun. The second is, that if a variety of colour resulted from a variety of density, that would at once prove that all the stars, except these coloured ones, had a uniform density, which is more than analogy requires. But it is an obvious error to suppose, that a difference in the colour of the light indicates a difference in the degree of a star's density; for we know that the effect of an atmosphere upon light depends quite as much upon the force of gravity as upon the mere density of the sun or planet it surrounds

—quite as much upon the extent as upon the consistence of the atmosphere; and that, for this reason, the density of a star is not indicated by the colour of its light. Do we not see Jupiter and his moons shining with the same difference of colour as we see in a large proportion of the binary stars—blue, and whitish orange—yet we know that this, in his case, does not result from the difference of density.

2. As to the second suggestion of this dashing theorist (or bold guesser, as he seems to call himself,) that a different degree of heat *may* indicate a different degree of density,—we receive not the slightest hint from him of the means by which we may know whether one star is hotter than another, or why we should even imagine that there is any difference of this kind between the stars; and even if we could ascertain in any given case that one star had a higher temperature than another, we know that the suggestion thus thrown out is incorrect; we know that a different degree of heat does not indicate a different density. The density of Jupiter is precisely the same as that of our sun, yet the sun is manifestly hotter than the planet. We have,

therefore, no evidence either in the colours of the binary stars, or in any other phenomena, to justify us in concluding, contrary to analogy, that the density of the stars is not the same as that of the sun.

It appears desirable to have enlarged thus much upon the elements of our knowledge respecting the density of the fixed stars; but beyond the advantage of ascertaining the truth respecting it, it is of little moment to our present inquiry: for one sun being to any extent more or less dense than another, would not in the slightest degree interfere with its solar fitness, as the above writer admits, nor would a greater amount of density in one sun than in another—however much greater that amount might be proved to be—detract to any appreciable extent from a very strong general resemblance otherwise between them.

What has been said of the weights of the stars and of their density is true also of their *brightness* and of their *heat*. A certain amount of heat is inferred to attend a certain amount of brightness in the fixed stars, and a certain amount of brightness to attend a certain weight

or mass, and this inference is made from their analogy to our sun, even by the writer just alluded to, who is compelled by his theoryso much to disparage this analogy. Such is the universality of assent upon these points.

The *shape* of the stars is inferred to be spherical, not however from analogy alone, but also from the great principle connected with gravitation, that materials whose particles can mutually attract each other, lapse naturally into that form.

The rotation upon their axes, and the *periodical regularity* of this or whatever other movement they may have, are also looked upon as universal attributes of all the stars, and that only from their general analogy to our sun. Neither of these properties, as far as we can judge,seem to be essential adjuncts of universal gravitation, and there are but few of the stars in which we can say that we *see* the phenomena connected with these properties taking place. The general resemblance, however, of the sun to all the rest of the stars, convinces us that he is as like them in the rotation upon his axis, and in the regularity of his periods, as he is like those in which we discover these phenomena with the telescope. Even the

writer who has sought most to detect (if it had been possible) any little point of dissimilarity between sun and star, says that, "probably all the stars rotate"—that "revolution upon the axis is, so far as we know, a universal law of all the large compact masses of matter which exist in the universe, and may be conceived to be a result derived from their origin, and a condition of any permanent, or nearly permanent, figure. By such rotation of the separate masses, the whole is put in a condition which is everywhere one of stable equilibrium."

Finally, with regard to *origin*, it is accounted one of the most undoubted portions of human knowledge, that in this respect also a sun and a star resemble one another. Those who hold the most opposite opinions as to what the real origin was, are agreed that it was not one thing for one star, another thing for another star, a third for our sun, and so on; but that whatever the origin of one was, was the origin of all. There are in modern times but three classes of those who think upon the origin of natural objects. One class of thinking men hold that each of the heavenly bodies has been separately and absolutely created out of nothing

by the Almighty, in such a special sense that every one of these bodies is just *as* and just *where* He intended it should be, and that if He could be supposed to have forgotten any one of them, or not to have been actually and separately occupied about each of them, they could not have begun their present existence; nor could they even now continue to exist as they do (either by means of a system of laws, or in any other way), if this same sort of minute care and attention were not now unintermittingly continued. Another class hold that this distribution of care is in the last degree incredible, and that therefore the creation of the material universe was otherwise conducted. They hold that the Almighty created, in the first instance, in this way, out of nothing, and by a distinct act of attention, an immense quantity of nebulous matter (some speak of it as "fire-mist" or "star-dust"), in a chaotic state; that this chaotic mass, once created, could maintain its own existence without any further thought or care on the part of the Creator, and that He invested this matter while in this chaotic state with certain star-making, sun-making, planet-making, plant-making, and animal-making (some even

think spirit-making) powers, which should render it perfectly independent of this constant supervision, through every its minutest operation; and that, having done this, He abandoned it to its self-development, in such a sense that it neither receives nor needs any subsequent care or attention upon His part, and could exist even if He could be supposed to forget its existence. According to these writers, no star and no planet resulted in any part of space from His immediate and direct intention, but in some unexplained way, from a contest or agreement between the planet-making and star-making powers.

A third class, unable to think that God either wholly watches, or wholly neglects, His creation, hold an opinion which they mistakenly believe to lie between these two. They hold that He, in the first instance, indeed created a chaotic mass of matter, and implanted in it the above powers and laws, or others productive of the same effects; but that, instead of abandoning it to the self-development of these powers and laws, He not only, to a certain extent, maintains the existence, every instant, of the whole mass, but to a certain extent also superintends and ap-

points its every individual act in every part of the universe at the same moment, and that if He did not, to some extent, do this, these laws would not be fully observed, nor these powers fully act, and the chaotic mass itself would become more chaotic. All these three classes of thinking men are agreed that *Alpha* Centauri, or Sirius, or any other of those extremely distant isolated, self-luminous bodies which we call stars, has had the same origin as the one we call our sun. Those who look upon our sun as having either partially or wholly originated with a chaotic mass of nebulous matter, careering through space and self-developing, extend this strange theory to *Alpha* Centauri and Sirius, and do not pretend to claim for our sun any special method of creation different from that of all the other stars, and those who look upon the projection of *Alpha* Centauri into space as a distinct, personal, and *present* act of an Omnipotent Spirit at whatever moment that event took place (nor has it ever been explained how it is possible for the veriest sceptic to have any other thought but this about it), do not seek to say that this was not the case with our sun also. So true is it

that a community of origin is conceded by all parties to star and sun.

Such are the ten unseen, or inferred characteristics, in which our sun resembles the rest of the fixed stars, and in which all are agreed that the resemblance is established, unless in any given case in which it can be shown that it does not hold, none which has ever yet been pointed out; and (again we repeat) it is merely to prove this resemblance that these characteristics are here adduced—merely in answer to the question, "In what respects is our sun like the stars?" and not by any means, as some have imagined, that we seek to show a necessary connexion between planetary systems like ours and suns like ours—a confusion of the argument that can hardly be introduced by any intelligent man who is not aiming more at sophistry than at truth in our inquiry.

Of the partial characteristics of the fixed stars:—

1. *Dark spots upon their discs.*—Many of the stars are observed to undergo partial obscurations, recurring regularly at various intervals of

time. In some stars the obscuration returns after intervals of a few days, or of a week; in others, of a few months, or of a year; in others, of several years; and these things are seen in all parts of the heavens. The conclusion universally arrived at respecting the shorter intervals is, that these obscurations result from dark spots upon the surface of the stars indicating changes of some kind there, similar to those which we see to be taking place in our sun, and to be indicated in him by similar dark spots upon his surface. We are already able to discern from thirty to forty stars, which all exhibit more or less a likeness to our sun in this particular. Of course we can only detect the dark spots upon such stars as have either very large ones, or a great many of them; for all the stars are so far from us that we never see their discs, nor even more than the few rays that survive the ethereal medium of a great many billion miles, the largest pencil of rays that reaches us in this way being what we call a star of first magnitude. A diminution in these few rays is all that we detect with the telescope, and a very slight variation in this delicate index is sufficient to

attest a large group of spots, but we have no reason to think that in any case more than half, or, perhaps, a quarter, of the star's disc is covered, if nearly so much. The star *Omicron*, in the Whale, commonly called Mira Ceti, seems to be one of those with the largest quantity of these dark spots, inasmuch as at our great distance from it they render it wholly invisible to the naked eye during nearly half its revolution, although at other times it is a star of second magnitude. That this peculiarity unfits it for the solar functions of imparting light and heat there is not the smallest reason to suppose, for the variation of the seasons can be effected as well by a sun revolving on its axis in about a year (as that star seems to do), and giving much less light and heat from one of its sides than from the other, as by the inclination of a planet's axis to its path around a sun of uniform brightness. But even if Mira Ceti could be shown not to be so well fitted for solar purposes in consequence of so many dark spots, as our sun is, which is far from having been shown, it proves only the more signally on this account, that the stars are more or less liable to having the same

dark spots upon them as our sun. Our analogy does not require us to believe that every sun is in every respect exactly the counterpart of every other; nor that our sun should have exactly, or even nearly, the same amount of these dark spots as all the other stars. Besides, that such large spots as those of the few stars we speak of, are not usual, or even frequent, upon the stars, is evident from the fact, that although all the stars turn all their sides to us, any spots that there may be in the great majority of cases, are too small or too few to be observable even in the stars that are nearest to us. Nor are our sun's spots always so minute as might be imagined. The changes which we find him undergoing in the atomic arrangement of his surface, and which, as in the case of the stars, are betrayed to us by these dark spots upon his disc, must sometimes be very considerable. In 1779, Sir William Herschel observed one 50,000 miles in diameter, occupying nearly forty times the space our Earth would occupy upon the sun's disc; and they are often so large as to be visible to the naked eye. Some look upon these phenomena in the heavenly bodies as marks of decay;

others, as marks of progress; others, probably with more justice, as neither indicative of the one nor of the other. It has been very recently observed, that probably the sun's spots do not appear upon the same side like those of the stars, and that probably those of the stars are not always changing their size and position upon whatever side they occupy, as those of the sun are changing theirs. But these are some of the haphazard guesses, by aid of which it has been lately attempted to complicate as much as possible every point of this very simple question. There is not the slightest pretext for either of these notions, and both of them are contrary to analogy. We may add to this the following remark from the Edinburgh Encyclopædia: "Sir William Herschel suspected that one half of the sun emits less light than the other; and that when seen at a very great distance, it may appear like some of the fixed stars that have a periodical variation of lustre." Now is it not in the highest degree remarkable, that many of the most distant stars present the same phenomena in this respect as our sun, and that in all probability all of them have some of these dark spots upon their discs?

2. *Their orbitual revolutions.*—We see, by the aid of the telescope, that the universe of stars (at least as far as we can see it) consists of several thousand large groups, or starry firmaments, of form and size extremely various, placed at strongly marked distances from one another,—*i. e.*, distances immeasurably greater than even those enormous intervals which are also seen to be between the stars of the same group. The concisest and most general conjecture which reason has yet been able to suggest respecting these great starry firmaments (or aggregations) and their stars, is that, while the firmaments themselves revolve in unknown orbits around their common centre, and in periods imperceptibly slow, constituting thus a firmamental system, every star in every firmament does the same,—revolves around the general centre of its own firmament in an orbit and in a period greater,—as well as with a velocity less—in proportion to the greater distance of each star from that common centre. But even in the case of our own firmament, we have but very few facts corroborative of this conjecture. We have neither yet discovered the

common centre of its gravity, nor perhaps the orbit, nor the period of almost any such revolving star, nor, except in very few cases, the velocity with which the revolution is effected, or, except in these few cases, even the mere fact of any movement in the stars at all. After giving a few illustrations of the identity thus subsisting between the revolution of individual suns, and the rotation of a whole firmament of them, Dr. Nichol makes the following remark:—

"We are all too easily inclined to look on creation as made up of isolated parts—of independent or individual classes of beings, and to regard nature as we do a case of botanical or mineralogical boxes; so that it requires a fact as striking as the identification of the stellar motions of revolution with those of rotation, to startle us from the habitual error, and to bring us to right views of that stupendous order within which we live and of which our own beings constitute a part. The unity of things—their interdependence—their adjusted relationships, are proclaimed by every department of the universe. I deny not that different laws may exist,—nay, they *must*; for it is only by the

commingling of opposites that variety and progress can be produced; but all is not opposition which seems so, and most of what we divide and parcel out into isolated bundles, is nothing other than the parts of the same grand scheme. Philosophy has taught this for ages,—it is in fact the secret of her life; for she aims to gather up all fragments and to present the universe united, compact, tending to one end—a type of its August Creator." Whether all these revolutions of stars and firmaments have sufficient evidence or not, it is unnecessary here to inquire or determinate. We only mention it as an hypothesis connected with this part of astronomy, and towards which a sufficient number of facts tend to give it interest, and to suggest its modification.

One matter placed beyond all doubt is, that we *see* in a great many cases bodies supposed to be self-luminous stars, performing revolutions in orbits just as our planets do, and completing these revolutions in regular periods proportioned to the extent of the orbits. In some cases we have *seen* these orbitual revolutions completed in periods varying from forty to sixty years;—in

others it is calculated that they will be completed in hundreds of years;—in others, the periods are several thousands. However probable it may be that some of these supposed self-luminous stars—especially those with the smaller orbits—are really opaque planets, made luminous by their suns, it is improbable that others are, whose orbits and periods exceed all analogy to those of our opaque planets. It is calculated that the star Mizar, the *Zeta* of the Great Bear, revolves in an orbit which it cannot complete in less than about 200,000 years. The *Mu* of Cassiopeia, a single star of fifth magnitude, makes a greater annual progress in the heavens than any other star; yet the curve of its orbit is so slight that it as yet indicates no centre. Here then also how immense must be the orbit! "And a *great many* others," says Sir John Herschel, "have been observed to be thus constantly carried away from their places by smaller but not less unequivocal motions, motions which require whole centuries to accumulate before they produce changes of arrangement such as the naked eye can detect." Thus then many of the stars are self-luminous planets; and this

is known of so large a number, that many cautious and profound astronomers do not scruple to consider it most probable that they are all so. Now, even in this, our sun is like the stars. He also is a self-luminous planet. That most unlooked-for circumstance in any case,—that the so-called Fixed Stars have not only a movement on their own axes, but another movement, through space, by which they are carried round distant centres in orbits of their own, is true of our sun also. On this point Sir John Herschel says: "No one who reflects with due attention on the subject, will be inclined to deny the high probability—nay, certainty—that the sun has a proper motion in *some* direction." And this can only be orbitual; for there is no such thing known among the heavenly bodies as a rectilineal movement. In the "Architecture of the Heavens" it is spoken of as "a settled question, that the sun is moving in some grand path towards a point in the constellation Hercules. The discovery of the laws of this motion," continues the author, "of the nature of his path, and the amount of his velocity, is necessarily reserved for after times, but the main fact can-

not now be doubted. * * Many of the stars have also well established motions of their own; proving that they too partake of that scheme of external revolutions by which the sun is affected, and indicating, with the highest probability, the prevalence of an arrangement and co-ordination of this description, and of inconceivable vastness, through the whole central mass of our firmament." "Astronomers have not only placed beyond doubt," says Sir David Brewster, in his recent work upon this subject, "that the solar system is advancing in absolute space, but have determined the direction in which it moves, and within certain limits the velocity of its motion." So undisputed is it that our sun has this orbitual revolution like other stars. What centre he moves round we do not yet know with certainty, however obvious the conjecture that it is the general centre of our firmament. We only know that it must be immensely distant from him, because the movement still seems to us rectilineal, the curve obtained by the observations of almost a century inappreciable.

We may further observe that it has been recently calculated by Struve and others that

this revolution of our sun with all the bodies which depend upon him, around his distant centre, proceeds at the rate of about 150 million miles annually, (or four times slower than the earth's progress in her orbit), which would give upwards of 900,000 million miles for the sun's progress in his orbit since man's creation; and about 15,000 million miles (or five times Neptune's distance from the sun) since the movement was first observed, or rather suspected, by Dr. Halley. But it is to Sir William Herschel that we owe the invaluable suggestion that the attractive force capable of producing this effect is most probably not lodged in any one large body, but in the centre of gravity of a cluster of stars, or in the common centre of gravity of several adjacent clusters. He omitted, what appears perhaps most probable, the common centre of the whole firmament.

Here again we find the ingenious theorist seeking to divert attention from the overwhelming influence which our sun's movement in an orbit is calculated to exercise upon the present investigation. The fact itself that our sun has this orbitual revolution, like so many

other stars, he does not deny. He even admits, though not with much frankness, that the various attempts made in different parts of the world, to give mathematical certainty to it, have been successful, and that the whole subject is replete with interest and importance, yet he affects to think it irrelevant to our question; he affects to think that what we have to prove is a *necessary* connexion between life and orbitual revolution, and says that there is nothing of the kind in this case, any more than there is between the marine animal and the tide. But he well knows that no one ever pretended that there was. He well knows that his misconception is affected; that all we seek to prove by the sun's orbitual revolution, is likeness and analogy, and that it would be difficult to imagine a more unequivocal or impressive proof of this than this unexpected and stupendous revolution.

3. *Their being grouped.*—It has been already observed that all the fixed stars are seen to exist throughout space in immense clusters or groups (not to be confounded with the little clusters that are within our own firmament), widely separated from one another, and chiefly of

a circular or oval form. Now it is regarded by all the most exact and profound astronomers, not only as being obviously in the very highest degree probable, but as admitting of distinct demonstration, that our sun is placed within one of these large clusters. Sir William and Sir John Herschel, as well as other distinguished men both here and on the continent, have been at the pains to investigate the external proportions resulting from the various distances of the various stars around us, and have thus succeeded in delineating the form of the group in which we are, and in indicating our position in it, while others have pointed out, in the remoter regions of space, other groups, of forms very similar to ours; and one of these among the most distant often attracts the telescope towards it, which is found to possess all the peculiarities of external proportion and form that we discover in our own.

The reader can have no difficulty in seeing that if he were placed exactly within the central portion of one of these groups, of the globular form, in which the stars were all equally distributed, the stars would appear to him to be

equally thick and at distances equally graduated, in all directions around him, as well as below him and above him. There would be no difference in this respect in any direction of his heavens, night or day. But it would be otherwise if he were not situated exactly at the centre, at an equal distance from every part of the external surface of the group. If his position were towards one side of this globe of stars, he would have the stars much thicker in one direction than in another; and in the direction in which he would see them thickest, there would be one point in which they would seem more so than any other, on account of the globular or spherical form of his firmament. That point would be his galaxy, or Milky Way; and thus every star of such a group, that is not within the most central region of the group, has its galaxy or crowding of stars as a natural result of its position within the group, and of this position being rather towards the circumference than at the centre.

The reader can also see that if the group, instead of being a sphere is the section of a cylinder—having the form, for instance, of a

millstone, or of a very thick medallion—and he is placed within the central portion of the starry firmament so formed, the stars would appear to him very close and crowded, when he looked from his central position within it towards its circular parts; and, comparatively speaking, but thinly scattered when he looked towards either of its flat sides,—because immensely more stars lie between him and the circumference of his medallion firmament than between him and these, its flat sides. Now, when he reflects that the long and crowded tract of stars which we call our Milky Way runs all round our heavens, and is as much above us in the day as it is at night, while to the east and west of us the stars are comparatively but very thinly scattered, he will at once understand, as from a geometrical demonstration, with what truth the astronomers describe the group of stars in which our sun is placed as of this medallion form, and our sun's position as somewhat towards the central regions of the group.

Those who wish to pursue this subject further may do so with advantage, for there are peculiarities in some of the outlines of our Milky Way

which he will find accounted for—1. By carrying in his mind the extremely oval form which in so many instances we see the centrifugal force communicating to the rim of these flat circular firmaments. 2. By supposing two such firmaments, placed side by side, instead of one (a peculiarity of structure discernible in the distant group already alluded to as resembling ours). 3. By assuming a position somewhat more towards one circumference, as well as more towards one of the outer flat sides, than we have spoken of; and 4. By attention to the lengths of starry medium through which the sight travels from that position to the different points in the two circumferences. The greatest of these lengths make the stars in our Milky Way appear the closest, the smallest, and the most numerous; while the shorter lengths, towards the circumferences, efface the effect of the oval rims to the eye.

But such details are here unimportant. We are now in a condition to see that every star in a globular firmament, except those in its more central region, has a Milky Way, in relation to it, of some kind or other; that in a circular flat firmament like ours, every star, without excep-

tion, has its Milky Way; that all the stars that are in the same region of it as we are, have even exactly the same Milky Way or galaxy as we have; and, which is the main point to be attended to, that no heavenly body of any kind—no sun, no planet—could possibly have a circular galaxy like ours unless it occupied a position within a stellar group of some description; that, therefore, our sun is grouped with the fixed stars. What could imply community of nature between him and the stars, if it is not implied in this? What could prove analogy between them if this does not prove it? No one can pretend that any one star in such a group is more likely to have planets round it than another; and it is not only with the stars of his own group, or with the stars of such groups as exactly resemble it, that our sun becomes thus identified by this great modern triumph of scientific research, but with the stars of all the other firmaments that hang around us in the abyss of space. There are, as we have said, thousands and thousands of these large stellar groups discernible at an incalculable interval around and outside our own group, and these are to be

found as far off as the most powerful of our telescopes can reach, and every star in every one of these is thus proved to be upon a par, in nature, with our sun.

Of the external similarity between our group and some of the others, one of which is described as a perfect *fac-simile* of it, much interesting matter is here necessarily omitted. Of the groups generally, Sir John Herschel says,—"They are almost universally round or oval; their loose appendages and irregularities of form being, as it were, extinguished by the distance, and only the general figure of the more condensed parts being discernible." The oval form is that which the circular flat groups—the thick medallions, as it were—assume when it is the edge or rim of the group that is presented to the telescope, for the thickness of the medallion becomes gradually less and less from the centre to the edge. This edge view he describes as a pretty long oval, increasing by insensible gradations of brightness, at first very gradually, but at last more rapidly, up to a central point, which is very much brighter than the rest. Of the round forms that he mentions, some of course may be these

oval groups seen from the side instead of from the edge; some, however, are manifestly spheres, as is evident from the great and graduated blaze at the centre of the circle. Of these, he says, —"Many of them indeed are of an exactly round figure, and convey the complete idea of a globular space filled full of stars, insulated in the heavens, and constituting in itself a family or society apart from the rest, and subject only to its own internal laws. * * * On a rough calculation it would appear that many clusters of this description must contain at least ten or twenty thousand stars, compacted and wedged together in a round space, not more than a tenth part of that covered by the moon. Perhaps it may be thought to savour of the *gigantesque* to look upon the individuals of such a group as suns like our own, and their mutual distances as equal to those which separate our sun from the nearest fixed star; yet, when we consider that their united lustre affects the eye with a less impression of light than a star of the fifth or sixth magnitude (for the largest of these clusters is barely visible to the naked eye), the idea we are thus compelled to form of their distance from

us, may render even such an estimate of their dimensions familiar to our imagination; at all events, we can hardly look upon a group thus insulated,—thus *in seipso totus, teres, atque rotundus*, as not forming a system of a peculiar and definite character. Their round figure clearly indicates the existence of some general bond of union in the nature of an attractive force."

4. *The white colour of their light.*—This is a point of likeness so obvious as to need no remark, were it not that its importance might escape attention. In natural objects, known or supposed to be like each other in other respects, similarity of colour indicates the closest possible similarity of nature, and the fewer those particulars are by which it is in our power to judge of likeness in any case, the greater is the importance which we attach to this similarity of colour. Upon both these grounds the similarity of colour in starlight and sunlight is of very great weight. In all analogies colour is so. It is by its aid, in fact, that we for the most part judge of distant objects whose shape and size are obliterated by the distance; the mere fact of an object being distinguished to be black or white, blue or yel-

low, being often sufficient in such cases to give us a very high degree of certainty respecting it.

Now we find in some cases that the heavenly bodies, so like each other to all appearance in other respects, are differently coloured; and so far are we from thinking this difference likely to be unattended with any other difference, that the thing is never done—the difference is never thought of as unimportant. We may not always be able to account for the peculiar colour; but we never think of it as without some peculiar cause—some different peculiarities of nature—in or at the star in which we find it. In the stars that emit their own light, no one for an instant supposes that any peculiarity of colour discoverable in their light does not result from a corresponding peculiarity in their nature and qualities; and, as the necessary consequence of this, it is looked upon as highly probable that no considerable difference of intrinsic condition in such bodies could subsist without producing a corresponding effect upon their light. For this reason the ordinary and natural conviction is that all the stars of the same colour are much in the same internal condition; and it would be

considered unreasonable to think otherwise,—unreasonable to suppose that, although all the stars are of the same colour, all of them, or most of them, have this internal condition different. In this case, more perhaps than in any other of the kind, both on account of the great number of the objects, and the extremely little that we know, independent of analogy, respecting them, the importance of colour is immense. In judging of any new star that might make its appearance, it would be matter of primary consideration; and so likewise, when we ask ourselves what we should think of our sun if it had never been otherwise placed than as the other stars are—viz., at such a distance that its disc could be no longer seen; and if the quantity of rays flowing from it that now reach us from Sirius, were of the same white colour exactly as that of all the other stars, would it not have been most unreasonable in us to single out that one star as the only one of countless myriads of the same colour that was to be supposed to be of a different nature from all the rest? And this similarity of colour, which would have been so important in an analogical

point of view, if we could not see the sun's disc, is of no less importance although we see it—of no less importance to enable us to appreciate the identity of his condition and nature with that of other stars; and here all that we are concerned to establish is this identity. It is physically impossible that a body placed at such a distance from us as to have no disc, should be altered in its nature merely by being placed so near us as to subtend an angle of thirty minutes; and if the difference between a dark-green light and a white light is of importance in judging of the nature of two bodies with discs that cannot be seen, it is of no less importance in judging of this nature in two bodies of whose discs we can see only one.

But it is said there is no necessary connexion between white light and a system of planets. This is true; but it is not necessary to prove any such connexion in order to show how important we nevertheless consider white light to our sun and to the stars. If our sun began to shine from to-morrow with a very dark green light, our feelings would soon teach us our convictions on this point. We should not only think that a

great difference commenced from that hour between the internal nature of our sun and of the stars. Few would look upon it as an unreasonable apprehension that the dissolution of the system was at hand. Who would be influenced in such a case by the suggestion that there is no necessary connexion between opaque planets and white light? Or if, the sun remaining as he is, the stars were from to-night to assume this dark-green colour, who would not see in such an event the cessation of identity between the nature of our sun and of the stars? What believer in the stellar planets could witness that event without the awful thought that this change of colour might have been attended with the termination of all those happy worlds? Necessary connexion there is none; but why these fears, if colour indicates no analogy?

It is probable, then, that as the discs that are unseen are like the one that we can see, in having the same colour, instead of having, as they might have had, some colour or colours very different,—it is, we repeat, most probable that the elementary composition of the seen is little different from that of the unseen, except,

and only except, in cases in which it can be shown to be otherwise—most probable that if this composition were essentially dissimilar, the colour of the light emanating from it would not be the same. That reflected light should differ without any difference in the nature and condition of the reflecting orbs, especially after passing through incalculable tracts of the ethereal medium, and from orbs of a magnitude disproportioned to such distances, as well as from the atmospheres of these, of various extents and densities, is intelligible enough. We see, for instance, from the position that we occupy, a difference in the colour of our moon and in that of the other secondaries of our system, although we have every reason to believe the nature of all these bodies to be the same, and a difference between the colour of Uranus (bluish), and of Jupiter (orange), and of Mars (red), without the slightest grounds for suspecting that this difference results from dissimilarity of nature in these three bodies. How reflection and refraction can produce red, blue, and yellow, from orbs of the same nature is easily explained; but light that is projected by the orbs them-

selves is, if it is different in different orbs, a sure index of a nature at least somewhat different, or, if the same, of a nature somewhat the same. In the one case the natural connexion is manifestly there; in the other manifestly not.

Besides, do those who have been taught to think of the other stars as a set of bodies very different in their nature and qualities from our sun never wonder to find them emitting, thus, a light of the same colour as he emits? Do they never ask themselves by what law of nature this is likely to happen? Or, on the other hand, the fact of our sun—a body supposed so unlike a star—not being dark green, nor dark blue, nor any other colour of the great number that we might name, but only the colour, the exact colour, of the stars—orbs so unlike him, as we are led to suppose, that he should have, with a studious preciseness, the very same shade of colour as they have, instead of any other; this surely must strike us as a very singular circumstance, highly calculated to excite our suspicions as to this supposed difference of nature, and enough of itself to make us reconsider the matter —to make us ask why should we think the other

stars unlike our sun? Is there any necessity for supposing the unlikeness? Can we not in any way get rid of so inconsistent an hypothesis?

But this analogy, although we advert to it to show the importance of the resemblance in question, is not our present business. All we need here attend to is that there is a remarkable likeness of colour between starlight and sunlight,—that this point of resemblance is a very important one in analogies, especially in such analogies as do not present us with many features to judge by; and, most of all, important in judging as to a difference or similarity of nature in self-luminous orbs.

The only writer of any note who labours under the singular impression that most of the fixed stars must be very unlike our sun in their qualities and nature seems to have been led to this conclusion, notwithstanding this remarkable similarity of colour, by arguments and reasonings which, however skilfully combined, can have very little weight with the generality of people. In the first place, he makes a "bold guess," as he expresses this sort of speculation, that we have no knowledge of what ordinary readers will

think so obvious a fact—no knowledge of the stars being like the sun in the colour of their light; and, in another page, endeavours to justify this speculation by some interesting astronomical facts. Elsewhere he suggests that process of dialectics already described, applicable not only to the colour of the stars, but to every point of likeness, seen or unseen, that we can discover in our sun and them, resulting in the conclusion that even if the likeness in any given respect existed, it would be of no use of any kind in an argument derived from analogy, and therefore of none in that connected with the stellar planets. Let us, however, first attend to his denial, and the facts which seem to give it countenance.

While most people consider their white colour to be quite as remarkable a point of likeness between the orbs we are comparing, as their being self-luminous, and one much better known, he writes thus:—"The stars, it is said, are like the sun. In what respects? We know of none, except in being self-luminous." (Chap. viii. sect. 29.) No reason is assigned—no explanation.

We read, however, in another page what ap-

pears to be the only ground he has for thus ignoring or denying the similarity of their colour, viz., the varied colours of the binary stars. He adduces these colours as evidence that, although the sun has and can only have white light from his self-luminous nature, the stars can have coloured light as well as white light from theirs—that, therefore, the stars cannot be said to be like the sun in colour, and that consequently their nature must be very different from that of the sun. "It is observed by astronomers," says the learned author, "that in the pairs of binary stars, which we have mentioned, the two stars of each pair are of different colours; the larger stars being of a high yellow, approaching to orange colour, but the smaller individual being in each case of a deeper tint. This might suggest to us the conjecture that the smaller mass had cooled further below the point of high luminosity than the larger; but that both these degrees of light belong to a condition still progressive, and probably still gaseous. Without attaching any great value to such conjectures, they appear to be at least as well authorized as the supposition that each of

the stars, *thus different*, is nevertheless precisely in the condition of our sun." (Chap. viii. sect. 6.) And again—"And that the matter of the stars does go through changes we have evidence, in many such changes which have actually been observed, and perhaps in the different colours of different stars, which may not improbably arise from their being at different stages of their progress." (viii. 13.)

Now, it is an undoubted fact, and an exceedingly interesting and important one, that in the binary and ternary stars, where the magnitudes are very unequal, the larger constituents are, as has been already observed, of the same white light as the rest of the stars and our sun; while the smaller star in these little constellations is invariably either what observers agree to describe as "dusky," or of some decided prismatic colour, such as blue, red, orange, green, and rose-coloured; some are grey. But in all this there is nothing to warrant "so bold a guess" as that white light is not as completely the intrinsic colour of the fixed stars as it is of the sun. In the first place, as the author seems to be quite aware, the bodies described as the smaller con-

stituents of the binary and ternary stars are strongly suspected by the highest authorities in astronomy, of not being self-luminous stars at all, but opaque planets, much larger, probably, some of them than those of our system, revolving round their different suns as ours do, and shining by the reflected light of these luminaries. This is not the occasion to enter upon this direct evidence of the opaque stellar planets. We need only observe that this very strong suspicion at once disqualifies these bodies as evidence to prove the hypothesis of there being stars of a different colour from that of our sun, and of the sun not, therefore, being of the same nature as the stars. But, in the second place, even if it could be shown that these coloured bodies were self-luminous stars, this difference in their colour proves to us, as that author justly observes, that they must have some peculiarities of some kind, which make them different from our sun and the other stars not thus coloured. Hence the rest of the stars, differing from them in these peculiarities as well as in their colour, are in all such peculiarities thus proved to be like our sun. In either case, then, we see that the coloured

stars afford no foundation for this author's singular "guess." We see that if these coloured bodies are really self-luminous stars they only prove the more clearly and vividly how much the rest of the stars are like our sun in colour; and, on the other hand, if it can be proved that they are not self-luminous stars at all,—that they are too much cooled down and dimmed for the stellar nature, and have neither the "luminosity," nor the thermal condition requisite to constitute them suns and stars, this would only be the greater proof that the bodies that really are self-luminous stars are like our sun, and this, not in colour only, but in other conditions also.

The application of this writer's dialectics need not occupy us long. The test of likeness which he proposes, would proceed thus:

The stars it may be urged are like the sun in this, that they have a white colour, not blue or green like the suspected stars. In this, however, the stars resemble not only the sun but gas-lights and comets' tails, for these also shine with light of a white colour. A star then being like the sun in having a white light, does this fact prove that the one body is not a million

times more dense than the other? Are not the stars, or at least a good many of them, in a state a million times more diffused than our sun, or even still more so, but visually contracted to points by the immense distance from us at which they are. That this is their diffused condition is, it is true, but a probable guess. It is, however, all the likeness between them and the sun suggested by their common colour. If any person is not satisfied with this account of the degree of resemblance between the fixed stars and the sun, but would make the likeness greater than this, we have only to say that the proof that it is so lies upon him. Such a resemblance as we have supposed is all that the facts suggest. That the stars shine with a white light we see; but whether they are or are not a million times more rarefied and attenuated than the sun we have no means whatever of knowing, any more than as to whether they are not a million times more dense; and to assume that beside these visible bodies with a white colour, there are invisible bodies without a white colour revolving round the others upon certain principles of gravitation—and to assume these invisible bodies upon no

other imaginable grounds than in order to superinduce upon this another still wilder assumption—another immense concourse of invisible bodies living upon the other invisible bodies, is an hypothetical procedure, which, &c.; and further, a star it is said is like the sun in shining with a white light. To this we reply that we know this only of those stars in which the very phenomenon which proves their white light, proves also that they are unlike the sun, in giving us less of it. Add to which, their white light is not necessarily connected with the existence of planets, still less, of inhabitants of planets, in any intelligible manner. The resemblance therefore, even if it existed, would have been shared with objects totally different from star and sun, and would not necessarily imply living bodies or even revolving bodies; and being thus but an ambiguous and inconclusive point of likeness, could contribute nothing whatever to an argument from analogy.

Of the erroneousness of such reasoning every reader can judge. We can only repeat what we have already said. It is not requisite that any

given point of likeness should be exclusively confined to the objects undergoing comparison. It is not requisite that we should be able to infer any one quality from any one other quality, either probably, or as a necessary consequence. It is not requisite in analogies that there should be a necessary consequence of any kind connected with the given point of likeness. It is not requisite that an analogy should be able to rest wholly upon any one of the several points of resemblance that can be adduced to sustain it.

5. *Their central position to the orbitual revolutions of other bodies.*—It has been already mentioned that all the stars discoverable within the most distant limits of space exist at enormous distances from one another, in gigantic groups or firmaments, which groups are also separated from one another by intervals so much greater than those between the stars of the same group as to have the effect of placing the groups themselves in as complete isolation with regard to one another, as each star of the same group is itself placed with respect to those around it; so that it is equally true that the stars are all grouped, and yet that they are all individually

in complete isolation. It has also been mentioned that a great many of the fixed stars of our group, as well as the one we call our sun, are found to have each a distinct orbitual movement of its own, and that now all stars are supposed to have such, to which it is difficult as well as unnecessary to assign any other centre than the common one of the whole group; and this, notwithstanding the ordinary impression, need not by any means or in any case, be either a self-luminous or an opaque body—either a visible one or one invisible; for we know that the laws of gravitation do not require or even admit of this; we know that all the materials, for instance, that enter into the composition of the earth are attracted, not to any one definite portion of the internal substance, but to a mathematical point at the centre, which constitutes the centre of gravity to the whole mass.

Now further: Our telescopes show us a great number of the stars of our own group that have other immensely distant bodies revolving round each of them, precisely in the same way as we see the planets of our system revolving round our sun; and in periods sometimes greater, sometimes

less than the greater periods of our system. These distant bodies are thus therefore carried, in their attendance upon their suns, around the general centre of our firmament, just in the same way as the planets of our system are carried with our sun around the same common centre, and not very unlike the way in which our moon is carried round our sun in her attendance upon the earth. This is peculiarly observable in what are called the binary systems; in most of which it is placed beyond all doubt that stars not only can act but do act as suns or central forces to planets exactly in the same way as our sun does. Whether the planets of these systems are, as so many still think, and as still seems true of so many of them, self-luminous bodies, attended each by its own opaque planetary system, or whether they are all of them, or most of them, opaque bodies, which there seems to be so much reason for believing that the smallest of them certainly are, is in this place of no importance. All that is of moment to us just now is that thousands of self-luminous stars are now seen acting as centres of planetary systems in which the orbitual revolutions are established upon

"the same evidence," says Sir John Herschel, "that we have of those of Uranus and Neptune about the sun." It would seem that six thousand of these central suns, with the largest of their attendant planets, have been already counted; and the discoveries of M. Struve—"the highest living authority in this department of astronomy," as he is called by the same Herschel, himself among the highest in all—suggest the idea that all the brighter stars are rendered thus bright to us, not merely, as must to some extent be true, by a lesser distance, nor at all as one or two speculators have imagined, by being larger than our sun, but by having one or more of these large planets revolving round them (these large planets themselves perhaps consisting each of them of a whole planetary system such as Jupiter's)—a luminous effect which would to some little extent be produced even by our own small opaque planetary system upon the apparent magnitude of our sun, if seen from the same distance as we now see Sirius. From M. Struve we learn that many of what we call stars are planetary systems of which the central sun would, if alone, be scarcely visible to us, at least

not as a star of the same magnitude as when seen in conjunction with his planets; and we know with the utmost certainty that there is a point in space, from which, in the same manner, our own planetary system, however far this system may extend beyond Neptune, appears like but one bright star. "He examines," (we are told of M. Struve,) "especially the brighter stars—those comprised between the first and fourth magnitudes—and arrives at the conclusion that *every fourth star* of such stars in the heavens, is physically double (multiple). He even ventures to assert that when we have acquired a more complete knowledge of double stars, it will be found that *every third bright* star is physically double (multiple). It appears by his researches, that one third of the fixed stars differ from our sun in the broad fact of not being single masses, but systems of two or *more* luminous masses lying *near* each other or revolving about one another." Here, it must be admitted, is a singular amount of likeness between the self-luminous stars and our sun—an amount of it extending to many—we cannot tell how many—not improbably to all the fixed stars.

It is not impossible that some theorist may cavil at this, and, if the revolving bodies in these cases can be proved to be self-luminous, tell us that the very same phenomenon which proves the stars to be central suns, proves them also to be very unlike our central sun, in being such to self-luminous bodies instead of to opaque ones. But this is obvious cavilling. Even in the systems (if there be any), where the planets that we can discern can be proved to be self-luminous, and thus the unlikeness greatest between the other suns in question and our own, what nevertheless can exceed the likeness between these unlike suns? Even if this were the sole resemblance that we had to go upon, what can we speak of as analogy, if we cannot speak of this as such? and as to the supposed only point of difference—that the one sun has self-luminous planets and the other not—it remains to be proved that it exists; it remains to be proved that the circumrevolving bodies are, in any of the multiple stars, self-luminous as well as luminous—self-luminous like our sun, as well as merely luminous like Jupiter—which nothing has yet been observed

in these bodies to render probable, much less to prove. But even if it were true that our great central solar force were unlike many of the other great central solar forces now discovered, inasmuch as they have planets that are self-luminous (in addition to any merely luminous ones that they may have), revolving in regular orbits and periods round them, of this at least there can be no doubt, that something very analogous to this is taking place around our sun in the circumrevolution of his own opaque planets, and quite enough to constitute a very strong point of resemblance between these central suns and him.

6. *The Elliptical orbits of their planets.*— It is ascertained in the clearest manner, that the Fixed stars produce upon the orbits of the bodies revolving round them the peculiar effect of causing these orbits to run, not in regular circles, but in ellipses, from one focus of which, in each case, the central solar force, or fixed star, exerts its influence upon its planet,—an effect exactly similar to that produced by our own central solar force upon the revolution of the bodies circulating round it. Here then is an exactness

of resemblance between our sun and the other fixed stars, in what we may speak of as their solar instincts, which is truly astonishing.—What guess can we permit ourselves to hazard for the future, founded upon difference between star and sun, after such a discovery as this?—We are asked to point out in what respects the stars are so like the sun as to lead us to believe in an analogy between them—as to make it probable that they are like him in the particulars in which we cannot (it is supposed) see them to be so. It is a fair demand, and is here answered. But on the other side we ask, what amount of likeness would satisfy the inquirer that such a point as this will not satisfy. Is there any extent of resemblance—any number or character of points (short of the solitary one to be proved by analogy, viz. that they have opaque planets) a known resemblance in all of which would produce conviction in such a mind? If there is not, then the case of that mind is peculiar as well as intractable. If there is, let it be stated what that likeness, what those points are, that in such an inquiry, one is entitled to expect. Much less, it will be acknowledged, would suffice,

than the extremely close resemblance implied in the elliptical orbits, of which it is now placed beyond all doubt that star and sun are alike centres.

This fact, it is true, is one in which (as we are reminded by the Essayist) the fixed stars resemble, not only our sun but our earth, whose moon's orbit is elliptical; and it does not imply, he tells us, any particular state of condensation or diffusion, leaving it optional to suppose the stars a million times more dense than our sun, or a million times less so; nor does it appear to be necessarily con-connected with opaque planets in any intelligible manner, for Uranus has some of his moons in circular orbits; and it would not perhaps, he suggests, appear to every one to be of itself sufficient to justify us in inferring from analogy, the opaque stellar planets that are in question; all which conditions are, we have seen, the test of likeness proposed by this writer as proper to be employed when we investigate an analogy. But it will hardly be thought that for any of these reasons the other fixed stars are not like our sun in the form of the orbits in which they preserve their planets; nor will it be thought

that this point of resemblance between other suns and ours is not a very striking and a very interesting one.

7. *Their position in regions where opaque masses are known to be in periodic movement.*—If we had evidence that, physically speaking, there could not be, or that there were not opaque bodies in the portions of space that are occupied by the fixed stars, our analogy might here have received a check; but we know with as much certainty as the distance admits of our knowing almost anything that is going on there, that there are such opaque masses in some way or other connected with the fixed stars in every direction of the heavens. It is observed that several stars—at least forty—undergo periodical obscurations, to a various extent, and at various intervals, from two or three days to twenty years; and it is thought exceedingly improbable, if not physically impossible, that the obscuration, which is in most cases pretty rapid both in its appearance and disappearance, should result from a commensurately rapid increase of the star's distance from us in consequence of its revolution in some great orbit. It is therefore believed

that either there are, as has been already mentioned, opaque masses which present themselves as dark spots upon the stars' discs (as in our sun's case) which come round from time to time, as the star rotates upon its axis, causing thus this diminution of the light, or that there are large opaque planets, or systems of planets, like Jupiter's system, but, in some cases, probably much larger, revolving in regular periods, round them, by which their light is occasionally intercepted either wholly or partially from our view. "In order to explain these singular changes (of brightness) astronomers have supposed that the stars are suns, having parts of their surface occupied by large black spots, which in the course of their rotation about an axis present themselves to us, and thus diminish the brilliancy of the star. Some astronomers suppose the black spots to be permanent; but others are of opinion that the self-luminous surface of these bodies is subject to perpetual changes which sometimes increase their light, and at other times extinguish it. The variation in the light of the stars has also been ascribed to the interposition of the (opaque) planets

which revolve around them; but it is not probable that the planets are sufficiently large to produce any sensible effect. Even when seen from the earth the light of our own sun is not perceptibly impaired when Mercury or Venus are passing over his disc." (*Edinb. Encycl.*) Although this latter remark is true of Venus and Mercury, it might not be equally true of all the greater planets of our system, if seen at once in transits on various portions of his disc, even if Jupiter, Saturn, and Neptune were, which is most improbable, the largest of our planets.

Besides, the obscuration of a star by its opaque planets to the spectator in a distant system is not effected solely, nor even mainly, by their obstruction of its light, but also, to a very considerable extent, by their not contributing their share to the general illumination of their system, which occurs while they are in all that part of their orbit that lies between their sun and the supposed spectator; for the distant eye sees the light of each system, as if it were diffused over the whole area within the orbit of its remotest planet, and then brightest when most of the planets have most of their illuminated discs

towards the eye. Hence we see that it is a mistake to suppose that opaque planets could only produce these obscurations by the very partial and insufficient effect of an occasional transit;—a consideration which adds considerably to the probability of the obscurations being produced by opaque, and not necessarily very large planets.

In the judgment that we form of the phenomena in question, respect must be had to the length of the periods. Where the period is two or three days, it is in the last degree improbable that the obscuration should be dependent upon the revolution of a planet, or even of many planets; the necessary rapidity in the one case (if there were no other objection), and in the other the singular interrelation necessary between the orbits of several planets, to produce the required effect, are both improbable conditions. In such cases, therefore, it is more natural to attribute the obscuration to dark spots upon the disc. But where the periods are of great length, twenty years—ten years—even one year—it is equally improbable that dark spots should be the cause of the obscuration. A rotation upon an

axis that lasts a year or twenty years, would be, even in the case of a sun much larger than ours (if we had any reason for supposing such), something that would strike most people as highly improbable. In these cases, and they are the many, we seem to have no alternative but to infer opaque planets, and to account for the apparent periodical obscuration of the star by the real periodical obscuration of its opaque planets,—a result precisely similar to that which occurs when our moon becomes periodically obscured to us in consequence of her position with reference to the sun. In general, however, it is not supposed, nor is it necessary, for the point of likeness here indicated, to infer, that the opaque masses which cause the obscuration are detached from the luminary; for this would be, as we have seen, nothing more or less than the opaque planetary systems that are in question. It is enough for us to know that the presence of bodies that are not self-luminous, in those regions, has been acknowledged by all the astronomers as in the highest degree probable. It may, however, be mentioned as a remarkable and curious fact in connexion with this inquiry,

that in the case of the periodical star, known as Medusa's head, or Algol, the peculiar manner in which the obscuration takes place and ceases, has always appeared to astronomers, notwithstanding the shortness of the period, as likely to result from the presence and intervention of a planet of the same opaque nature as those of our system. After describing this peculiarity, Sir John Herschel says: "This remarkable law of variation certainly appears strongly to suggest the revolution round it of some opaque body, which when interposed between us and Algol, cuts off a large portion of its light; and this is accordingly the view taken of the matter by Goodricke, to whom we owe the discovery of this remarkable fact, in the year 1782." In this case (says the only English writer who disbelieves in the stellar planets), the "obscuration of the light and the restoration of it are so sudden, that from the time when it was first remarked, it suggested the hypothesis of an opaque body revolving round the star." And again: "The revolution of Algol seems to approach the nearest to a fact in favour of a star being the centre of an (opaque) revolving system; and

from the first, as we have said, the periodical change, and the sudden darkening and brightening of this luminary suggested the supposition of an opaque body revolving about it. But this body cannot be a planet." This fact alone seems to prove with direct evidence the existence of those planetary systems which it is our present object to show the reasonableness of deducing from analogy alone. All however that we now infer from it and the other periodical stars, is that there are large quantities of matter subject to periodical movement, and not self-luminous, in some way or other—it is unnecessary here to determine how—connected with the fixed stars of our firmament, and that in this respect also these fixed self-luminous stars are like our sun, both as he appears to us from our orbit, and as he would appear to us from a distance at which our whole illuminated system would be contracted to a point.

Finally: *There is no one particular in which our sun is known to be unlike the other fixed stars.*—It is allowable in analogies that very considerable differences should subsist, provided they are counterbalanced by a sufficient amount of resemblance

in other respects, and that the latter fully and fairly preponderates. In fact, where there is no known or supposed difference, two or three points of resemblance are sufficient to constitute a very strong analogy. Between star and sun, however, there is not only an amount of resemblance extending to all the minutest requirements of opaque planetary systems sufficient, as we have seen in going over the selected points, to establish a very clear and close analogy, even if the points of difference had been considerable,—even if, for instance, our sun could have been shown to be 500 times greater or smaller, or 500 thousand times less dense or more dense, than the other stars; but it appears, moreover, that no difference of any kind has been detected even by the most vigilant research of modern times,—that, on the contrary, every fresh discovery of the telescope, shows the likeness to be stronger and stronger, besides confirming all the likeness that had been previously discovered. What amount of likeness, then, that is not the absolute and ascertained sameness that is in question, can exceed this?

The likeness of our own solar star to the

other stars of the universe being thus confirmed, and placed beyond all reasonable doubt, by the progress of astronomy, and that too in the clearest and most unexpected manner, the next question is: Does this likeness warrant the assent so universally given by astronomers to the popular belief that the spaces around the other stars are occupied in the same way as the space around ours, and that the great majority of the stars, if not all of them, have each an opaque planetary system of its own, bearing some resemblance more or less exact to that in which we are,—having, for instance, each, one or more primaries, and each of these, one perhaps, or even several secondaries? We say more or less exact, for the combinations of nature are, it must be remembered, profusely various. Or can we adopt the gratuitous assumption that luminaries found to be so like in everything—and in nothing unlike—differ from one another in so important a matter as that of having or not having opaque planetary systems? Can we assume that one of them has such a system but the others not? The obvious answer is that we cannot; that if we find one of them

with such a system we must assume, as matter of course, that the rest of them have it also, or at least that most of them have. It is not only that we are warranted in concluding thus. If we are in earnest,—if we have a care about the truth, and a wish to be as near it as possible, we are constrained to do so;—we are constrained by the extent of the known likeness to assume, as in the highest degree probable, that the stars have such systems as we know that suns have, viz., opaque planets in periodic movement around them, and that the planets already discovered around the stars are opaque; and this being the case, we have, by a similar though more obvious analogy, at least one world of intellectual creatures connected with each star.

As to the proportion of the stars which may be regarded as being suns of opaque systems, and as to the number of planets probably belonging to each system, we need say nothing, and can say but little. Humboldt, indeed, suggests (Cosmos, III. 373) that it is not "absolutely necessary" to suppose every one of the smaller stars to have a planet; and that if we reason by analogy from our own system, only

five stars out of every eight can be supposed to be suns, as three of our primary planets have no secondaries. But this reasoning is false; there is here no such analogy. In the first place, we have not the slightest reason, assigned or assignable, for supposing (as is here done) that there is as much difference of size between any two of the fixed stars as there is between the earth, which has a secondary, and the smaller planets which have none. In the second place, should we not think it contrary to all analogy to suppose that if there is another large planet beyond Neptune, it is little more than an even probability (five to three) whether it has or has not moons. In the third place, we know the purpose of a moon just as we know why a flower has a stem, and we can therefore point out why a large planet requires a secondary and why a small one does not; but even if we had any reason to suppose one star as much smaller than another as Mercury is than the earth, what analogy can there possibly be between the twilight powers of Mercury and the solar powers of a star? How can we suppose the one without a planetary system for the same reason as the

other is without a moon? But, fourthly, there can be little analogy in this question, between a secondary and a primary planet, notwithstanding the confusion into which the Essayist and others have fallen upon this subject. We may look for complete analogy between secondary and secondary, or between primary and primary, or between sun and sun; but not, as the Baron supposes, between primary and sun; and still less, as both he and the Essayist pretend to do, between secondary and primary. We do not argue the probability of primaries around the stars from the presence of secondaries around our own primaries. This would indeed be a loose analogy. It is evident that if there were no secondaries at all around our primaries, we should still have all the reason that we now have for believing that there are primaries around the stars. Humboldt's remark therefore affords us no guide either as to the proportion of opaque planets in the stellar systems, nor as to the proportion of the stars that may be without such systems. The passage will be found in another page. But even when he insinuates the *absolute necessity* of sixty per cent. of the fixed stars

having attendant planets, we cannot look upon such language as appropriate.

The author of the Essay on the Plurality of Worlds—the only modern philosopher of note (if we except Dr. Cullen) who seeks to make out an improbability as to the existence of the opaque stellar planets, does not express so very positive an opinion on the subject as some of his readers seem to imagine, and as he himself seems sometimes anxious to have it supposed. He does not deny, for instance, that our sun is one of the fixed stars, and one of the fixed stars a sun. All he pretends to assert is, that the other fixed stars, however much like this one, and however much like suns they undoubtedly are in other respects, *may* possibly not have the necessary peculiarities for rendering them centres of opaque planets as well as of self-luminous ones; for he seems to hold, but without assigning his reasons, that the stellar planets already discovered are most probably self-luminous like the stars they revolve round. That the fixed stars are very likely to have opaque planets, and the necessary peculiarities of heat and density for having opaque planets, he does not positively

deny. He thinks it would be rash to deny this. He admits that it is a perfectly natural conclusion from analogy to suppose that they have them, especially as some are found to have as many of these peculiarities as are requisite for the luminous planets (which he believes to be self-luminous) whose light can be seen at a much greater distance than he supposes that Jupiter's could, and which must therefore be bodies of considerable magnitude. He admits that this is a conclusion from analogy that the more the mind was enlarged and enlightened, the less it could resist; and that no one who does not hold the author's own peculiar views in Theology, Geology, and Nebular Philosophy, is at all in a condition to dispute. He admits that the only question that needs to be examined is, as to whether there is an analogy or not, and seems upon this point to have had his doubts mainly stimulated by these peculiar views, especially by his geological views, as well as, to some extent, by his misconception of the passage in Humboldt's Cosmos above alluded to, and a somewhat singular mistrust of all modern astronomical discovery. He even admits that the general

impression has grown up into a settled belief in a very stern and exacting age, and goes so far as to acknowledge, amidst an unusual display of learning, eloquence, and frankness, that all his objections to the settled belief respecting both the planets and inhabitants are only of this theoretical general description, founded, to use his own favourite expression, upon a bold guess suggested by his Geology,—that any special evidence that he can discern in favour of his own opinion, as to there being no opaque stellar planets, is indeed slight, and that in an astronomical point of view he does not look upon his opinion as quite exempt from temerity and precipitation. He admits, however (without further evidence), that it is most probable that some of the stars have opaque planets, although not many; and that both the stellar planets and the rest of those in our own system are inhabited by brute animals, his geological and theological views forbidding only the inference that any other planet in the universe, except the earth, should have moral inhabitants. In his theory there is no objection to brutes to any extent, where they are physically possible. In short, the

whole of this agreeable little book, (for such we doubt not many will regard it, notwithstanding its lamentably retrograde character,) is not more remarkable for the unparalleled want of faith in our modern astronomical discoveries, which is betrayed in almost every page, than for the enlightened candour with which it is acknowledged that the only question connected with the opaque stellar planets is strictly one of analogy, and of nothing else; and that that connected with the planets of our own system, in which the analogy is no longer at issue, is now wholly one of physical possibility. He writes thus:

"The argument that the fixed stars are like the sun, and therefore the centres of inhabited systems as the sun is, is sometimes called an argument from analogy. But it must be recollected that *precisely the point in question is whether there is an analogy.* The stars, it is said, are like the sun. In what respects?" (Chap. viii. sect. 29.)

"Humboldt very justly regards the force of analogy as tending in the opposite direction. 'After all, (he asks, Cosmos III. 373,) is the assumption of attendants to the fixed stars so absolutely

necessary? If we were to begin from the outer planets, Jupiter, &c., analogy might seem to require that all planets have attendants but yet this is not true of Mars, Venus, Mercury.'" (*Note.*)

"What, then, is the probability of that view? Is there any good evidence that the fixed stars, or some of them, really have (opaque) planets revolving round them? What is the kind of proof that we have of this? To this we must reply that the only proof that the fixed stars are the centres of (opaque) planetary systems, resides in the assumption that those stars are like the sun; resemble him in their qualities and nature, and therefore, it is inferred, must have the same offices and the same appendages. * * Everything in this argument, therefore, depends upon this,—that the stars are *like the sun;* and we must consider what *evidence* we have of the *exactness* of this likeness." (viii. 8, 9, 10.)

"Any special evidence which we can discern on this subject either way, is *indeed slight.* * * We may, however, notice a *few features* in the starry heavens with which, in the *absence of any stronger grounds,* we may be allowed to connect our *speculations* on such questions." (viii. 1.)

"On a subject on which *we know so little*, it is difficult to present any view which deserves to be called analogy." (viii. 30.)

"That Copernicus, that Galileo, that Kepler should believe the stars to be *suns in every sense of the term*, was a natural result of the *expansion of thought* which their great discoveries produced in them and their contemporaries. Nor are we *yet* called upon to withdraw from them our sympathy; or *entitled to contradict their conjecture*. But all the knowledge that the succeeding times have given us * * should, it would seem, have prevented that old and arbitrary conjecture from *growing up*, among a generation professing philosophical caution and scientific discipline, into a *settled belief*." (viii. 33.)

"The original assumption, a mere *guess, unsupported* by all that three centuries of most diligent, and in other respects successful research, has been able to bring to light." (viii. 33.)

"The reasonable view of the matter appears to be this. The assumption that the fixed stars are of exactly the same nature as the sun was, at first, when their vast distance and probable great size were newly ascertained, a *bold guess*;

to be confirmed or refuted by subsequent observations and discoveries. Any appearances, tending in any degree to confirm this *guess*, would have deserved the most considerate attention; but *there has not been a vestige of any such confirmatory fact*. No (opaque) planet, nor anything which can fairly be regarded as indicating the existence of an (opaque) planet, revolving about a star, has anywhere been discerned." (viii. 33.)

"Let us then go on to the cases in which we have proof of such gyratory (*i. e.* planetary) motions in the stars; for such are not wanting. Fifty years ago, Herschel (the father) had already ascertained that there are certain pairs of stars, very near each other, (so near, indeed, that to the unassisted eye they are seen as single stars only,) and *which revolve about each other*. * * Some of those pairs which have the shortest periods have already, since the nature of their movements was discovered, performed more than a complete revolution; thus leaving no room for doubting that these motions are really of this gyratory (planetary) kind." (viii. 3.)

"Being able thus to discern in distant regions of the universe, bodies *revolving about each other*,

we have the means of determining, as we do in *our own solar system,* the masses of the bodies so revolving." (viii. 4.)

"When the theories of Copernicus and the telescope of Galileo had proved to the satisfaction of *thoughtful* men, that the planets were in several respects like the earth; and had suggested the *guess* that the fixed stars were perhaps so many suns; it was *impossible to repress* the conjecture that the planets might have their inhabitants, and the stars their inhabited planets. This was at first a mere conjecture. Has the subsequent progress of discovery and reasoning tended to make it probable or improbable? * * The immense distance at which the fixed stars were proved to be, offered a reason why we may fail to see their planets. * * This vastness of the number of worlds which the universe was supposed to contain, though it disturbed the minds of some (?) had a charm for others; and by the occasion it presented for *lofty* phrases (?) and *large thoughts,* made the opinion of the plurality of worlds popular, in spite of the *religious* (?) difficulties which attend it." (*Preface.*)

"I am aware that it is a subject on which

many persons bestow very serious thoughts and feelings. *I, too, have my serious thoughts and feelings on the subject.* * * But if the serious thoughts and feelings which flow from a belief in the plurality of planetary worlds have really been produced by a *guess*, lightly made at first, *quite unsupported* by subsequent discoveries, and *discountenanced* by the most recent observations, though *too remote from knowledge* to be either proved or disproved,—what is there to prevent my speaking of such thoughts and feelings as mere results of imagination, and comparing the views on which they rest with those which I think to be more probable." (*Dialogue.*)

"It is probable that when we have reduced to their real value all the presumptions drawn from physical reasoning, for the opinion of *planets* and stars being either inhabited or *uninhabited*, the force of these will be perceived to be so small, that the belief of all thoughtful persons on this subject, will be determined by *moral*, *metaphysical*, and *theological* considerations." (*Dialogue.*)

"If any persons find *their* religious convictions interfered with, and *their* consolatory impressions

disturbed by what is said in this Essay, the author will deeply regret," &c. (*Preface.*)

"These views are so different from those hitherto generally entertained, and considered as having a sort of religious dignity belonging to them, that we may fear at first, at least, they will appear to many *rash* and fanciful, and almost, as we have said, irreverent." (Chap. x. sect. 12.)

"To conceive planetary systems as formed by the gradual contraction of a nebular mass, and by the solidification of some of its parts, is a favourite notion of several speculators. *If we adopt this notion,* we shall, I think, find additional *proofs* in favour of our view. * * The tendency of nebular matter to separate into distinct portions, which may afterwards be more and more detached from each other, so as to break the nebulous light into patches and specks, appears to be seen in the structure of the resolvable nebulæ, * * and, according to the view we are now taking, we may conceive such patches, by further cooling and concentration to remain luminous, as comets." (x. 6, 8.)

"The theory which we have ventured to propose of the solar system *agrees with* the nebular

hypothesis, so far as that hypothesis applies *to the solar system.* The nebular hypothesis, as it applies *to the universe* in general, is precisely the doctrine which I here *reject,* giving my reasons." (x. 16 and *note.*)

"The substance of all nebulæ is not continuous, but discrete;—separable, and separated into distinct luminous elements;—nebulæ are, it would then seem, as it were, of a curdled or granulated texture;—they have run into lumps of light, or have been formed originally of such lumps. But what are these lumps? How large are they? At what distances? Of what structure? Of what use? It would seem that he must be *a bold man* who undertakes to answer these questions. Certainly he must be *very* bold, &c. (Chap. vii. 12.) I call Arcturus and Sirius stars (*i. e.* points of strong light), because they are so. I avoid calling the dots (*i. e.* points of faint light) into which nebulæ are resolved, *stars,* because I do not at all know that they are objects of the same kind (*i. e.* points of light) as Arcturus and Sirius." (*Dialogue.*)

"It would be *very bold* to maintain that of all the innumerable stars which spangle the sky,

and which astronomers have hitherto held to be bodies of the same nature as our sun, *not one* is really like the sun, in having (opaque) planets revolving round him; and no less bold, it seems to me, to maintain that *many* have, or even that one has, *without further evidence.* * * *I do not pretend to disprove a plurality of worlds.* But I ask *in vain* for any argument which makes the doctrine probable." (*Dialogue.*)

"It is a possible conjecture at first, that there may be other worlds having, as this has, their moral and intellectual attributes, and their relations to the Creator. It is also a possible conjecture that this world, having such attributes and such relations, may, on that account, be necessarily unique and incapable of repetition, peculiar, and spiritually central. These two opposite possibilities may be placed, at first, front to front, as balancing each other. We must then weigh such evidence and such *analogies* as we can find on the one side or on the other. * * We find in our knowledge of what we ourselves are, reasons to believe that if there be in any other planet intellectual and moral beings, they must not only be *like* men, but must *be* men in

all the attributes which we can conceive as belonging to such beings. * * As to other systems which *may* circle other suns, the possibility of their being inhabited by men, remains, as at first, a mere conjecture without any trace of confirmatory evidence. It was suggested at first by the supposed analogy of other stars to our sun, but this analogy has not been verified *in any instance;* and has been, we conceive, shown *in many cases,* to vanish altogether. * * We are left with nothing to cling to on one side, but the bare possibility that some of the stars are the centres of (opaque) systems, like the solar system; an opinion founded upon the single fact, shown to be highly ambiguous, of those stars being self-luminous; and to this possibility we oppose all the considerations flowing *from moral, historical, and religious views* which represent the human race as unique and peculiar. The force of these considerations will of course be different in different minds, according to the importance which each person attaches to *such* moral historical and religious views; but whatever the weight of them may be deemed, it is to be recollected that we have, on the other side, a

bare possibility — a mere conjecture; which, though suggested at first by astronomical discoveries, *all more recent astronomical researches have failed to confirm in the smallest degree.* * * On such a subject, where the evidences are so imperfect, and our power of estimating *analogies* so small, far be it from us to speak *positively* and dogmatically. * * And if any one holds the opinion, on whatever evidence, that there are other spheres of the Divine government than this earth—other regions in which God has subjects and servants—other beings who do his will and who, it may be, are connected with the moral and religious interests of man; we do not breathe a syllable against such a belief; but, on the contrary, regard it with a ready and respectful sympathy. It is a belief which finds an echo in pious and reverent hearts. * * With regard to the planets and the stars, *if we reason at all*, we must reason on *physical* grounds; we must suppose, *as to a great extent we can prove*, that the laws and properties of terrestrial matter and motion apply to them also." (Chap. xii. sect. 18, 19.)

"The stars being the centres of such systems,

is proved by *analogy* from their resemblanee to the sun; but the evidenee of this resemblanee was always *very loose;* and beeomes the *feebler* the more it is examined." (*Dialogue.*)

"We have, I conceive, reaehed one of the points at which the difficulties which *astronomical discovery puts in the way of religious conviction*, begin to appear." (Chap. iv. seet. 8.)

"When it was diseovered by Copernieus and Galileo that Mereury, &c., were really in many cireumstances bodies resembling the earth, * * it was *inevitable* that the eonjecture should arise that they too had inhabitants. * * This was an *unavoidable* guess. It was far less bold and sweeping than the guess that there are inhabitants in the region of the fixed stars; but still like that, it was, for the time at least, a guess; and, like that, it must depend upon future explorations of these bodies and their conditions, whether the guess was eonfirmed or discredited." (Chap. ix. seet. 1.)

"If the laws of attraction, of light, of heat, and the like, be the same there (in Jupiter, &c.) as they are here, *which we believe to be certain*, the laws of life must also be the same."—(*Dialogue.*)

"Of the nature of the stars *we know scarcely anything,* except that they are seemingly self-shining, very nearly fixed (as to our sense), and exceedingly distant from us. In this state of ignorance to assert that they have, and *that they have not, attendant planets,* would be alike *rash.*"—(*Dialogue,* p. 21.)

Thus much will suffice to mark the limits of this author's view upon the question before us.

To illustrate the force of the argument by analogy from which we infer that the stars have opaque planets as well as self-luminous ones (if any are self-luminous), it may not be inappropriate to observe that it is the same as that by which we find ourselves compelled to assume that the stars are like our sun in being hot. We do not know this by experience in any case to be a fact. We only know that there is every probability of it, and even the most sceptical speculators have admitted it. The rest of the fixed stars are like our sun in so many important particulars that it would be unreasonable to suppose them unlike him in this. The following illustration is to the same effect. Let a stranger be supposed to enter a chamber in which he finds a

vast number of minute boxes—say 5000—arranged at equal distances from one another upon the floor in a circular group—all as far as he can judge similarly formed and ornamented, and all of the same size. Let him be supposed to take up any one of them at random, neither from the centre nor from the circumference of the group, and on examining it to find that it contains five pieces of gold. Can it be thought unreasonable after this that he should without further evidence regard it as most probable that all the other boxes, or at least most of them, contained similar pieces? Would it not be more natural and more logical that he should, from this fact alone, expect to find a similarity of contents in the many thousands of caskets that resembled each other apparently so closely in external appearance, than that he should assume from it as probable that none of the other boxes contained anything at all? Are there not, in such a case, 5000 chances to one that the box he took up is not an exception, in this respect, to all the other boxes? Or, to remodel the original question — let us suppose a rational being suddenly ushered into mature existence

an utter stranger to the proportions and circumstances of the material universe. Let us suppose him to take a survey of the stars—to have one of them singled out to his attention—to be then suddenly transported into the space that surrounds that star, and to find there a set of planets, mysteriously revolving round that star, deriving from it heat and light, and to all appearance placed there upon the same occasion and with the same design as the star. Is it possible, after this discovery, that he could resist the conclusion that most probably all the stars had the same appointments? Would it be reasonable in him to say that unless further evidence of it could be adduced none of the rest of them were at all likely to have anything around them half so extraordinary? Would it be common sense in him to think it even *equally* probable (or would this not rather be very bold and very rash?) that of the countless myriads of stars he saw around him, there was not a single one that possessed such planets as that star had, into whose neighbourhood he had been thus fortuitously conveyed?

Such is the argument from analogy, and it

never was more emphatically and beautifully complete than in the present case. We cannot wonder that even the most profound—the most exacting astronomers have declared it irresistible, and have stood astonished amidst their sublime studies, in the presence of that immense diffusion of life and worship which they thus found registered upon every one of the fixed stars.

The answer then to the first of the two questions which it is proposed to consider in the present Treatise, consists strictly of two parts: 1. The scientific certainties connected with the probability of there being opaque stellar planets, and therefore of there being living creatures inhabiting them; 2. The force of the analogical reasoning flowing from these ascertained facts, and the force of analogical reasoning in general, which part of the answer is, it is hoped, sufficiently full to obviate that confusion which some have created both for themselves and others respecting the application of such reasoning to the opaque stellar planets. We cannot, however, do better than conclude this portion of our subject by subjoining the following passages from the Preface to Bishop Butler's Analogy:—

"That which chiefly constitutes probability is expressed in the word 'likely,' *i. e.* like some truth or true event;—like it in itself, in its evidence, in some more or fewer of its circumstances. For when we determine a thing to be probably true,—suppose that an event has or will come to pass,—it is from the mind's remarking in it a likeness to some other event which we have observed has come to pass; and this observation forms in numberless daily instances, a presumption, opinion or FULL CONVICTION that such event has or will come to pass, according as the observation is that the like event has sometimes, most commonly, or ALWAYS SO FAR AS OUR OBSERVATION REACHES, come to pass at like distances of time or place, or upon like occasions."

"Probable evidence in its very nature, affords but an imperfect kind of information, and is to be considered as relative only to beings of limited capacities; for nothing which is the possible object of knowledge, whether past, present, or future, can be probable to an infinite Intelligence, since it cannot but be discerned, absolutely as it is in itself,—certainly true or cer-

tainly false. BUT TO US PROBABILITY IS THE VERY GUIDE OF LIFE."

"In questions of difficulty, or such as are thought so,—where more satisfactory evidence cannot be had or is not seen,—if the result of examination be that there appears, upon the whole, any the lowest presumption on one side and none on the other, or the greater presumption on one side (though in the lowest degree greater)—THIS DETERMINES THE QUESTION EVEN IN MATTERS OF SPECULATION."

"It is not my design to inquire further into the nature, the foundation and measure of probability, or whence it proceeds that likeness should beget that presumption, opinion, and full conviction, which the human mind is found to receive from it, and which it does necessarily produce in any one, or to guard against the errors to which reasoning from analogy is liable. This belongs to the subject of Logic, and is a part of that subject which has not yet been thoroughly considered. * * It is enough to the present purpose to observe that this general way of arguing is evidently NATURAL, JUST, AND CONCLUSIVE."

PART II.

THE PLANETS OF OUR SYSTEM.

SECT. I.—*Of Density, and the Force of Gravity on the Surfaces of the Planets.*

THE analogy between the earth and the other primary planets of our system is much more obvious and much more generally known than that between our sun and the other fixed stars. In the other planets, for instance, as well as upon our earth, we find summer and winter, water and atmosphere, poles and tropics, as well as temperate zones, wind and snow, morning and evening, day and night, as well as twilight, spring and autumn, moonlight and sunshine. Nor is it only in such important matters that they are like each other. The likeness is sustained in the minutest and most unlooked-for particulars. After mentioning one of these,

viz., the singular proportion existing between the intervals at which the different orbits succeed each other, and the periodic times in which they are completed, Sir John Herschel makes the following appropriate remark upon our earth and the other primaries:

"It is no longer mere analogy which strikes us—no longer a general resemblance among them, as individuals independent of each other, and circulating about the sun, each according to its own peculiar nature, and connected with it by its own peculiar tie. The resemblance is now perceived to be a true family likeness; they are bound up in one chain—interwoven in one net of mutual relation and harmonious agreement—subjected to one pervading influence, which extends from the centre to the further limits of that great system of which all of them, the earth included, must henceforth be regarded as members."

The knowledge of the planetary system now so generally diffused throughout all classes of the community, supersedes the necessity of our here exhibiting illustrations of the unmistakeable likeness thus unanimously reported by all astro-

nomers. We did so in treating of the fixed stars, but the planets are too well known to require it. And it is not only that the earth is known to be like the rest of the planets: there is no one point in which it is known to be unlike them; no one point, at least, except such as results necessarily from their numerical difference. More than one planet could not revolve in the same orbit, yet there are several planets. These planets have, therefore, different orbits, and the different orbits are at different distances from the centre. This was unavoidable, but with this exception—with the exception of the variety of circumstances necessarily resulting from this cause, the planets resemble each other with an exactness and a constancy calculated to convince the most sceptical that they have no radical points of difference of any kind between them.

Here, then, as in the case of the fixed stars, we have a complete analogy. Here, also, therefore, the same reasoning applies. The likeness of the planets to one another is too great—the absence of all essential dissimilarity among them, too manifest, as far as our knowledge re-

specting them extends—to warrant us in supposing that any one of them differs from the rest in any one unascertained particular—in any particular, important or unimportant, in which we have not clear proof of a difference. If, for instance, it were an ascertained fact that Mars was perfectly solid to the centre, every one sees at once how unreasonable it would be to suppose that nevertheless all the rest of the planets were most probably hollow to within a few hundred miles of the circumference—that, in short, it was not at all likely that any other one of the eight except this one was solid throughout;—every one sees how unreasonable such a supposition would be, unless indeed it could be shown at the same time that the perfect solidity of a planet's interior could *only* result from the special proximity in which Mars stands to the Sun. Or if, without any knowledge of the minerals of our earth, an intelligent being becomes acquainted with the fact that tin is found in the mines upon the planet Neptune, what should we think of him if he assumed, without proof, that although that distant one of the primary planets had some tin in its composition, yet none of the others were

at all likely to have any? What, we ask, should we think of such an assumption, unless he were prepared to show some exclusive connexion between the mineral in question and the peculiar position of Neptune in our System? When we consider the extremely close likeness discoverable between Neptune and the other primaries, would not such a conclusion, unsustained by positive proof, be the exact contrary of what is usually accounted reasonable in such inquiries? Thus, also, if it were accidentally discovered by the inhabitants of some other system that Neptune, Mercury, or any other one of our primaries were the seat of vegetable, animal, and rational life, would it not be contrary to the ordinary principles of human reason for such beings to regard it as most probable that our earth and all our other planets, were exempt from this condition, unless it were first well ascertained by them that there was something connected with the peculiar position of Neptune, Mercury, or such other planet, that exclusively adapted it for vegetable, animal, and rational life? or, which is in effect the same thing,—something connected with the peculiar position of the rest of the planets which could be demon-

strated to unfit them utterly for such purposes? And it is the same with regard to the planetary elements. If we find alumina and silicon, oxygen, azote, and carbon, to be among the constituent elements of Neptune, or of any other primary planet, upon what principle could we assume that these things would not be found on all the other planets, unless their heat, density, force of gravity, or some other supposed consequence of their distance from the sun, made it physically impossible for alumina, silicon, &c., to exist upon them?

The careless man will perhaps answer to all this: "Well, then, we know nothing at all about the matter;—we have no right to draw any conclusions one way or the other." But neither would this be true. We know a great deal;—a great deal now, whatever may have been our ignorance in former days. We know of a likeness between the planets now, that puts an end for the future to all gratuitous supposition of dissimilarity. We are no longer left the alternative of indifference. As far as our positive knowledge extends all is resemblance—a minute, striking, unintermitted resemblance; we have, therefore, a clear right

to infer—and are, in consequence of this right, distinctly under the necessity of inferring—that bodies so like, as far as our knowledge goes, continue alike even beyond our knowledge. If we refuse to look upon this as the most reasonable conclusion it can only be because, contrary to all reason, we look upon the opposite conclusion as nearer to the truth, or at least as of equal probability. Thus we have no alternative. We are compelled to consider all the planets (as we do all the fixed stars) like each other in all particulars, except in such as, it is known to us, can be of no moment, or in such as admit of positive proof that in them the planets are unlike each other. This is what is meant when we speak of analogy. This is what we call probable knowledge; and earnest men need not to be told that probable knowledge cannot be disregarded. It has even the force of certainty, where certainty itself cannot be had.

Except in such particulars as it is known to us can be of no moment, or in such as admit of positive proof that in them the planets are unlike each other. Now, no one alleges that the occupation of the planets by intellectual creatures is known to be a matter of no consequence in the designs

of the Almighty. We need, therefore, say no more on that point. But it would appear that there are some earnest persons who think that we have got this positive proof that the planets are unlike each other in particulars affecting the physical possibility of life and organization; persons who are well aware of the extreme similarity between the planets, and who appreciate the full force of the analogy in question, yet think that there are certain physical peculiarities in every planet that is either nearer to or farther from the sun than we are, which obviously unfit it for the same internal condition, either with respect to its materials or its inhabitants; which make it physically impossible, for instance, that animal bodies, or the roots, leaves, and fruits they feed upon, could subsist in it, and therefore that intellectual creatures with such bodies could not be found there. It is to remove the mistakes and misgivings of such persons that these pages are intended. It will be seen that there are no such physical peculiarities as are supposed, either in the inferior or superior planets, and that therefore the analogy in question retains its full force.

The two inferences derived from the analogy

are: 1. That the constituent elements of each of the primary planets (of Neptune, for instance) are, most probably, like those of every other; like those therefore of the planet third in order from the sun. 2. That each of the primary planets (Neptune, for instance) has, in all human probability, the same vegetable, animal, and intellectual life upon it as all the rest have; as that has therefore which is third in order from the sun. The only form in which our circumstances enable us to inquire into the scientific certainty of these propositions is thus: Are the constituent elements of the planet with which we are best acquainted, and the three forms of life known to exist upon it, physically incompatible with the different circumstances known to exist upon the other planets, in consequence of their different positions in the same system? This is, simply and singly, all that we have to attend to. Now, the only peculiarities of the planets, resulting from the different distances at which they revolve round the sun, that have ever been put forward by any one, as being at all calculated to prevent a similarity of materials and inhabitants in all of them, are these four: 1. The density

of materials at their surfaces. 2. The force of gravity at their surfaces. 3. Their amount of solar light. 4. Their amount of solar heat. It is supposed, for instance, that if iron were eight or ten times less dense and compact than it is on the earth, it would turn into water, or into something else as little dense as water; and that, therefore, in Saturn, where everything undergoes that amount of change, there could be no iron; and others think the same of water there, or upon Jupiter. They suppose that as everything upon Saturn is ten times, and on Jupiter four times less dense than here, water could not be found in those or the other outer planets, since water would cease to be water, if ten, or even four times less dense than it is with us; while, on the other hand, one speculator, more eccentric than the rest, asserts that, in all probability, these outer planets are composed wholly of water. On Jupiter, also, everything is thought to be nearly three times heavier than here, and such a weight, it is naturally supposed, would make a man unable to crawl. On Neptune, it is thought that there is no daylight, and as this would interfere with the vegetation

to which we are accustomed, and with the instincts of many animals, it is supposed that however well a mere spirit might get on there, the animal body of man could not do so, as there would be no food for it. Finally, on the same Neptune it is believed that there is no solar heat at all; and on Mercury, seven times more than the intensest heat under which negro life is possible, without probably any mitigation; whence it is implied, and not without a certain air of plausibility, that no animal or vegetable bodies that we can even imagine possible, would be able to subsist on either planet. It will be seen that all such notions are so completely groundless as to render it inexplicable that any one should have been found to assert them as constituting objections to planetary life. It will be seen that the supposed inequality of the solar heat and light on the different planets, and the supposed inequality in the weights of objects and substances upon them, and the supposed effects of a greater or less density upon bodies, are all suppositions utterly inconsistent with the ordinary facts of astronomy, and with the plainest prin-

ciples of inductive science;—it will be seen, for instance, that it is as certain as science can make anything, not present to the senses, that Neptune has as much of the solar light and heat as we have, and that Mercury has as little of it,—that none of the planets could consist wholly or mainly of water, nor their density deprive them either of water, or of any other substance known to us,—that even Neptune consists of the same materials as the earth, and that the materials of Jupiter, instead of being two or three times heavier, are rather lighter—a fourth lighter—than those of the earth. In all these respects, we have the most indisputable scientific certainty that the analogy of the planets to one another is as complete as in everything else.

It will be convenient to explain these matters in two sections. 1. With reference to density and the force of gravity upon the surfaces of the different planets. 2. With reference to the amount of solar light and heat upon the surface of each planet.

The atoms or ultimate particles of matter are naturally much closer together—much more

compactly collocated in some substances than in others. These atoms are of two kinds: 1, those of the elementary ingredients out of which any given substance is composed; and, 2, the atoms formed out of these—the minute ultimate particles into which the substance may be mechanically subdivided, without resolving it into its elementary ingredients. The closeness of the first or elementary atoms, is a result of that chemical action which we term affinity. The closeness of the second class of atoms—the compounds of the first—is effected by what is called the attraction of cohesion, and can be increased or lessened by mechanical means. It is found that in every kind of substance—solid, fluid, or gaseous—if a sufficient amount of pressure be applied, the constituent particles can be driven more compactly together than had been from the first effected either by their chemical properties or by the attraction of cohesion;—that is, in other words, the densest substance in nature is, to some extent, atomically porous, or has its ultimate particles at some little distance from one another, and can therefore have them further condensed to whatever ex-

tent a sufficient pressure can be brought to bear upon them;—and heat results from the condensation.

It is found that upon this nearer approach of the atoms to one another, an amount of heat, previously latent among the atoms, becomes perceptible, and is greater or less according to the amount of pressure that the substance undergoes. The effects of this, especially in the more compressible bodies, are sometimes very remarkable. "Fire can be evolved," says a popular writer, "from the common atmosphere by compressing a quantity of it suddenly in a tube, at the bottom of which a piece of tinder has been placed. The evolution of heat by these means, and other circumstances, lead to the conclusion that heat is an element mixed up with the atoms of matter, which it serves to keep at a lesser or greater distance from each other. Thus, as we squeeze the pores of a sponge together, and disengage the liquid which they held in cohesion, so, when squeezing or rubbing a portion of matter, do we disengage the heat which it contained amongst its component atoms. In all cases of the development of heat

by pressure, hammering, and friction, the cause is the squeezing together of atoms which had been kept asunder by the latent fluid, and which fluid must, as a matter of necessity, come forth and make itself sensibly felt or seen. Heat, then, is a principle of repulsion in nature, and in this capacity its uses are as obvious as those of terrestrial gravitation, to which it apparently acts as a counterpoise." It may also be observed, that the definite proportions in which the elementary atoms of matter are chemically united, seem to affect the facility with which the component atoms resulting from these can be farther mechanically separated from one another, and farther mechanically condensed; because we find the compressibility of these compound particles much greater in some kinds of substances than in others; and we know that it is not the closeness of such particles, but the definite proportion in which the still smaller elementary atoms are chemically united, that determines, in any case, the nature of the substance resulting from the combination of the latter. For instance, it is much easier to condense or contract the separable atoms in a piece of rock, than in a

piece of diamond, and in ice than in water. In fact, it requires so much force to effect this in the case of water, that this substance is considered as incompressible as the diamond, and a great deal more so than ordinary rocks. And although water is more dense than oil, iron than granite, and gold than iron, yet no amount of pressure could ever convert oil into water, or granite into iron, or iron into gold;—for no amount of pressure with which we are acquainted has ever been found to destroy the force of that chemical affinity with which the elementary atoms of bodies are united. And in the same manner as substances can have their volume diminished—perhaps indefinitely—by the condensation, or increased proximity, of their atoms, so by the farther separation of these atoms from one another, by whatever means effected, the volume of any substance can be indefinitely increased. But what force will separate atoms in the same way as pressure will bring them together? It is evident that where the condensation is effected by pressure, the rarefaction or separation of the atoms can be effected, in elastic bodies, by the removal of the pressure. In elastic

as well as non-elastic bodies, this effect can be produced by the introduction of caloric between the atoms. In proportion as we heat any substance we cause it to expand. The ultimate particles of which it consists stand off more from each other; and the heat, which is an imponderable substance, fills up the interstices, or pores, resulting from the mutual repulsion that takes place between these particles. But, though heat produces this effect whenever it is applied, and is universally present to some extent in all bodies, being found even in ice, yet the grand planetary agent in the expansion of bodies, and in the latent diffusion of the central heat towards the surface of each planet, is the centrifugal force. This is the true counterpoise to the force of gravity. It urges all the atoms of a planet's matter—all the atoms of the various substances that compose the planet—from the centre towards the surface with an energy not very different in degree from that with which the force of gravity urges all the same atoms in the opposite direction—from the surface towards the centre. The centrifugal force thus holds in check the amount of pressure which the force of gravity would

otherwise occasion; also, therefore, the amount of central heat which so much pressure is calculated to generate; and what is of no less importance, it enables the heat that is generated at the centre of a planet to pass outwards, in a latent state, through the strata of the interior, thus rendered more open and pervious, and thereby to co-operate with it in the dilatation of all the planet's substances.

So much for density. That stiffness and strength have nothing to do with it, will appear later. Let us next attend to what is meant by *weight*. Each of the ultimate particles of matter that enter into the various substances composing a planet, is dragged to the planet's centre by a certain force. This downward tendency is called the weight of the atom, and is of the same amount in all such atoms upon the same planet. A substance, therefore, which contains a billion of these to the cubic inch on any given planet, is not only twice as dense, but twice as heavy as one which contains but half a billion to the cubic inch. The term "density" is therefore used as synonymous with "specific gravity," (though in

reality it is not so,) when we speak of the relative weight of substances on any one planet; but these terms cannot be used in this way as synonymous when we compare the substances on one planet with those on another; for all the planets vary slightly from one another in the amount of force with which they draw the atoms to their centres. In fact, in most of them this force is different at the equator and at the poles of the same planet, because the centrifugal force is greatest when it works in the greatest circles, and these are, of course, at the equators. There the centrifugal force diminishes gravity more than it can do at the poles, and even on our earth, a diamond or a pound of gold taken from the equator would be found to weigh a little more at the north pole. A greater difference, however, than this exists between the force of gravity on one planet and that on another; Jupiter, for instance, as will be presently explained, drags towards his centre the substances on his surface, *i. e.*, all the several atoms of each substance, with nearly three times greater force than our planet does. Every atom of lead or water, therefore, on his surface is three times heavier

than here; that is, a pound weight of water taken from here to Jupiter would there weigh three pounds, without a single atom being added to the mass, and on being returned to our planet again, would be found to weigh but one pound, as before. If, however, before being brought back to our planet, this pound of our water undergoes on Jupiter's surface some diminution of its density—say that its atoms, instead of remaining as close together as they were, are, from some cause or other, driven three times farther apart from one another than they are with us, it is clear that the water will thus increase to three times its bulk, requiring a much larger vessel to contain it, but still weighing on that planet three pounds, and on being then brought back to ours only one pound, notwithstanding its great increase in bulk. From this illustration we see that, while the density of a body, *i.e.*, the closeness of its atoms, remains the same, its weight may vary; and that while its weight remains the same its density may vary. In other words, the weight of a body does not depend solely upon the force of gravity on the surface of the planet on which it is placed, but also, and quite as

much, upon the closeness of the atoms of the body, or, as it is called, its density: for if the atoms are multiplied three times, so that without increase of bulk, the body is made to contain three times more of these ultimate particles than before, it will, on the same planet, weigh three times more than it did at first; but on another planet that drags to its centre with three times less force, it will only weigh the same as it did at first.

Let us now examine what is the density of materials on the surface of the different planets, *i. e.*, how close or how distant from one another, the ultimate particles of the substances stand in the composition of each planet; and what is the weight of these substances, *i.e.*, what is the amount of the downward force of each atom upon the surface of each planet.

To ascertain these points, we must first ascertain what are the relative masses of matter in the planets, and what are their relative sizes or bulks, and their relative diameters; but as the bulk of a spherical body is the cube of its diameter (*i.e.* the diameter multiplied three times into itself), we have only to determine, in the

first instance, the relative mass, and the relative diameter of each planet.

The mass, or matter, of a planet (by which we are to understand its *atoms*, or *weight*, and not its size) is calculated by the effect which it produces upon any other planet that comes sufficiently near its path to be within the reach of its attraction. For such planets as have satellites, this calculation admits of great exactness; but even in the case of those that have no satellites, their occasional proximity to other planets affords abundant opportunity of estimating, with sufficient exactness, the force with which each either retards or accelerates a neighbour's progress, or diverts it from its regular path.

In this way it has been calculated that

Mercury's matter is rather less than	$\frac{1}{6}$	that of the Earth.
Venus's...............	$\frac{6}{7}$	,,
Mars's	$\frac{1}{7}$	,,
Jupiter's	340	times that of the Earth.
Saturn's	102	,,
Uranus's	15	,,
Neptune's............	20	,,

or, in other words, that he has twenty times more atoms, and therefore twenty times more power than the Earth in influencing the movements of other bodies.

The diameter of each planet may be thus relatively stated:—

Mercury, less than ½ that of the Earth.
Venus, very nearly that of the Earth.
Mars, rather more than ½ that of the Earth.
Jupiter, 11 times that of the Earth.
Saturn, nearly 10.
Uranus, more than 4.
Neptune, more than 4½.

With these measurements we can calculate the density of the various objects and substances upon the surface of each planet, and also the force of gravity in the same position; and this is a much more simple process than those who seldom think about such things imagine. The mathematical rules are, that the masses divided by the bulks (*i.e.* by the cubes of the diameters) give the densities, and that the masses divided by the squares of the diameter, give the force of gravity. But it is proposed to unfold the whole of this matter more in detail, so as to enable the

general reader to make the calculation for himself, and to see the reason of it.

To begin, then, with Mercury:—It has about $\frac{1}{6}$ of the earth's mass. If it had also $\frac{1}{6}$ of the earth's bulk, its density would equal that of the earth. But instead of this, it has only ($\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, but rather more) about one-twelfth of the earth's bulk. But one-twelfth is twice as small as one-sixth. Mercury is therefore $\frac{1}{2}$ less in size than would make equal density. But the smaller the bulk is, the greater density will the above amount of matter effect,—Mercury's density, therefore, is twice as great as that of the earth. But when we reflect how inconceivably minute that space between the atoms of bodies is, which alone is subject to the change in question, we cannot wonder that reducing this space to one half (which is all that is meant by doubling the density), or even reducing it an hundred times, gives an effect, in firmness, completely inappreciable to the senses,—as much so as it is inappreciable even to the imagination. Thus, when we hear that the cork, the iron, the soil, the atmosphere, and the water of Mercury are twice as dense as ours, we must remember that this greater compactness belongs only to the insensible, not to the sensible,

proportions of such things, and can only be rendered sensible by some resulting difference of another kind, such as buoyancy, weight, refractive power, &c. But this double density of Mercury must not be understood to imply that things there are twice as heavy as they are with us; for though, by the above calculation, everything contains little more than twice as many atoms in the same space, every atom there weighs little more than half what it does on the earth. "It has been found," says Dr. Lardner (Museum of Science and Art), "that on Mercury the weights of bodies are only half of those which they would have if placed on the earth." This is calculated as follows: It is the mass of matter in a planet—not its bulk—that attracts, and every planet attracts as if the whole mass (or weight) of its matter were at the centre. It is so with all the heavenly bodies, and according as the squares of the distances from this internal centre of each planet increase, the force of gravity becomes weaker and weaker; the surface of each planet being, of course, at the distance of a semidiameter from the centre. Now, Mercury having, as we have seen, only $\frac{1}{6}$ of the Earth's mass, would, if he had his surface at the same distance from his centre as the Earth's

surface is from hers, have every atom on his surface only $\frac{1}{6}$ as heavy as the Earth has. But his surface is nearer to his centre; his attractive power is consequently stronger on his surface than merely $\frac{1}{6}$ that of the Earth. His semi-diameter is rather less than half the Earth's. The distance from his centre to his surface is therefore rather less than half that in the Earth's case; and the square of that being (2×2) 4, we see that although he attracts with less than $\frac{1}{6}$ the force with which our Earth does, by virtue of his mass; he attracts with 4 times more force at his surface than we do, by virtue of his shorter diameter; so that he attracts with a force which we may speak of as a little more than 4 times $\frac{1}{6}$, or as $\frac{1}{6}$ of the quantity 4, which gives the same result—a little more than half. This makes the force of gravity on Mercury's surface nearly half that which it is on the surface of the Earth. Every atom of his atmosphere, therefore, weighs about one-half of what it does on the Earth; but, as we have seen, the atoms of matter are about twice as numerous in bodies of the same bulk on Mercury as they are here. We may, therefore, speak of Mercury's substances as of double the density the same substances have

with us, and their atoms as of one half the weight of ours; and thus we find that everything there is not only twice as compact in this sense and incompressible, but of about the same weight, bulk for bulk, as it is here.

A great misconception has gradually made its way into the estimates of the planetary conditions, in consequence of its being sometimes stated that one planet is as heavy as if it were made of lead; another only as heavy as if it were made of water; a third as light as if it were made of cork, &c. Such expressions only profess to give the average weight or density of all the different materials of the planets, and the relative density of none, because it is but natural to suppose that the same substances will be considered by all who read, to have the same relative weight and density in all the planets. In consequence, however, of such expressions, some readers are too apt to suppose there are no relative densities at all; whereas there are, and of two kinds: 1. The matter of a planet becomes gradually denser and denser towards the centre, on account of the gradually increasing pressure of the superincumbent mass, so

that the external strata of a planet's materials, as well as everything else on the planet's surface, are a great deal less dense than the same kind of substances in the strata of the interior. How much this difference is in the density of the strata of the planets it is not easy to determine; but we know that it goes on increasing inwards, until the pressure which gives rise to it is checked, as this pressure ultimately is, by the very heat which itself produces, as has been already explained in a former page. 2. In the outer strata also, alone, and even on the surface, there is, we find, every possible variety in the relative densities of the different liquids, solids, and gases. Cork, granite, water, azote, alumina, must not be supposed to be all of the same density in the same planet, merely because one density is assigned upon an average to all the materials of the planet. The more accurate mode of expression, then, in the present instance is, that the density of every kind of thing in Mercury is about double what the density of the same kind of thing is on the earth. One writer, indeed, would appear to have allowed himself to be still further deceived by the popular descriptions in

ordinary use, and seems as if he were disposed to imagine that one planet must be made wholly of lead, another wholly of water, another wholly of amber, and so on, merely because water, amber, lead, &c., have been sometimes employed to illustrate the average density or gravity of the various strata from the centre to the surface. We need not here enlarge upon so childish and obvious a misconception.

It may be thought that there is a manifest disproportion between the so-called compact materials of Mercury's surface and the animal strength with which we are acquainted; but this also would be a mistake. In the first place, we know by our own experience of material objects that the difference of density between two objects, of which one is twice as dense as the other—or even twenty times as dense—is (apart from the difference of weight, &c., which usually attends it) much more of a theoretical than of a practical fact,—and is not otherwise discernible by the senses, than in as far as the one is heavier, &c., than the other. Gold, for instance, is much more than twice as dense as iron, and more than twenty times as dense as ebony or even oak,

If ebony were as heavy as gold, who would suppose that there was so great a difference as this? In the second place, the animal frame is known to be, in this minute sense, twice as strong on Mercury as it is with us, and for the very same reasons as we know that the materials require this greater strength to manage them. Let us not forget this important fact. The muscular fibre and the osseous tissue in this planet of ours are, we repeat, known to be only half as firm and substantial in this sense as they are on Mercury, and known to be so from the very same source of information as we know of the difference in the compactness of the objects and materials upon which they are employed. All disproportion is thus at once removed, and there is therefore no reason for supposing the bodies of intellectual creatures, or of any other creatures, to be of any other dimensions or nature there than they are with us. Besides, what is more common or more natural, than that working from childhood with materials twice as close-grained as those of our planet should render such workmen as a race twice as muscular and athletic as our own? Is not this the familiar effect produced every day

among ourselves by the labours of the quarry, the smithy, and the spade? But even if we had not this everyday experience of how such things are, our astronomical knowledge of Mercury furnishes us, as has been said, with a sufficient account of the compact muscle and superior firmness of bone which counterbalances the supposed greater strength and compactness of the various substances upon the planet. Nor is the bird at any disadvantage in the denser atmosphere of that world, nor the fish within its denser waters. The muscle of both fin and pinion is there stronger and compacter (in the same insensible degree) than here.

On Venus the density of materials, and the force of gravity at the surface, are so almost exactly the same as on our own sphere, and are, therefore, so evidently consistent with all the vegetables, animals, and minerals with which we are acquainted, that it is not worth while to engage the reader in the fractional calculations respecting them. The mass is a little less than that of the earth, but so also is the diameter a little less. The proportions, therefore, come out without any, or almost any difference. If there is no reason then for supposing,

as there assuredly is not, that the chemical and physiological compounds above-mentioned, or their elementary substances, are peculiar to any one of the planetary worlds, there is as certainly no reason for supposing that they are not to be found in the one that is second in the series from the sun;—no reason, at least, for this supposition, founded upon the amount of compactness or of weight, to which such things are limited in that world.

As Mars has 1 of the Earth's mass, and rather more than $\frac{1}{7}$ of the Earth's bulk, the density of his materials—*i. e.*, their insensible compactness—exceeds that of the sphere which we inhabit by a very small fraction. A cubic inch of his lead, or of his ice, contains very nearly the same number of atomic particles as the same bulk of our lead or of our ice; and if each of these atoms weighed, on Mars, the same as here, every kind of substance, (solid, fluid, and gaseous) upon him would weigh a little more than the same substance does with us. On Mars, however, each atom weighs less than one half of what it does on the earth. His surface, indeed, is nearly twice as near his centre

as the Earth's surface is near hers; and his mass, therefore, attracts with (less than 2×2) about three times more force in proportion. But then this mass is seven times less than the Earth's mass. Now, if it were only three times less, the force of gravity, at their surfaces, would be equal. Or, if his mass were six times less, his force would be one half of hers. But his mass being about seven times less, the force of gravity on his surface is a small fraction less than half what it is on ours. Thus his atoms do not weigh quite half as much as ours do, but we have seen that he has rather more of them in the same substances. Things therefore weigh, bulk for bulk, in Mars, not quite one half as much as they weigh here. Thus water and lead have there rather more substance in them than they have with us, but less weight;—so much less that one pound of either, as weighed in that world, would, if brought to the Earth, be found to weigh more than two pounds. The sandy and clayey soils there are neither more nor less friable than those of our own planet. The atmosphere is as dense, and therefore supplies the same quantity of oxygen in the same

bulk—the force and muscle of the animal bodies are as firm and compact, and therefore require as much of it—the plants and trees as stout and upright—the roots and fruits as nourishing, being as close in texture as our own.

In fact, all that the analogy of nature leads us to suppose existing there, exists in all such respects just as they do with us, except that, bulk for bulk, they are all of them more than twice as light. Timber, and granite, and iron, and animal bodies, are as compact as here, but weigh twice as little. A strong man who would weigh in this sphere 180lbs., weighs only 80lbs. or 90lbs. in Mars. This difference, however, we must be careful to mark, is not one in that world any more than it is one in ours. The inhabitants are unconscious of anything of the kind, unless they have, as is most probable, the same knowledge of astronomy as we have, and have calculated that everything on our larger globe weighs nearly three times heavier than the same things in their world. And this at first must appear to them very extraordinary. They would most naturally suppose that our planet would be uninhabited, as people like themselves would be

here crushed by their own weight. But reflection would soon disperse such errors, and they would see that a stature less than their own, or a less dense substance, or a more sedentary life, or all these three together, might render existence very possible and even very agreeable to us: and they would also see (what we are now insisting on) that the universality of a difference annihilates it,—that however great this difference in the case of weight may be between any two planets, the same relative weights still exist in each, and that throughout the whole planetary system iron is everywhere four times heavier than silicon, and silicon twice as heavy as water, and water twice as heavy as ebony. The only difference then that results from the different force of gravity upon the Earth and upon Mars is, that for locomotive purposes physical strength goes more than twice as far there, and is therefore really that much greater for such purposes than with us. In this respect the bodies of the intellectual inhabitants are but upon a par with those of the unintellectual. The lion and the mouse, as well as the man, are able to spring and to run that much faster and farther. Man can wear

heavier clothing without fatigue when his climate requires it than he can here; and the horse which can here draw but one ton, could there draw nearly three. Yet the operations of the smith and the carpenter, the ploughman and the quarryman, are not much, if at all, less laborious than they are here. To split the rock, or to saw the plank, or to bore the hole through a piece of iron, is as hard for the inhabitant of Mars as it is for us. It is in carrying these things and in sustaining the weight of his own body that he seems to have the advantage over us. But these are small differences, and perhaps not much more than can be met with among ourselves. The grand fact remains untouched; as far as his density and force of gravity are concerned, there is no reason to suppose that the materials of that planet are not of the same nature as those of this; nor to suppose that the three forms of life with which we are acquainted—animal, vegetable, and intellectual—might not very well exist and flourish on the one surface as well as on the other.

The next of the globes in question is Jupiter. His diameter is found to be eleven times greater

than ours. His bulk is therefore (11 × 11 × 11) 1331 times greater. Yet the quantity of massive matter diffused through this bulk, is only 333 times greater than there is in our globe. In other words, it is found that he attracts distant bodies with no more than 333 times the force with which the Earth attracts them. As his bulk is 1331 times greater, his density would be the same as ours if his mass were also 1331 times greater. But his mass is four times less than this. (1331 ÷ 333 = 4.) His density is therefore four times less than that of the Earth,—about the density of our seas, or of amber. Thus in a cubic inch of Jupiter's lead, there are four times fewer atoms—the atoms are four times less close and dense—than in a cubic inch of ours. But let not any one suppose that this makes any difference in the appearance or ordinary properties of the lead—it is in every respect equally stiff—equally hard. The atoms of matter and the little distances at which they stand from one another, are so excessively minute—so utterly imperceptible—that great changes are able to take place among them without being a whit more perceptible than the minute objects themselves

among which they take place. In speaking of the density of substances this principle cannot be taken too much into account. Cork and feathers are also four times less dense than here; and little as these substances might be supposed able to bear a further diminution of their density and compactness beyond that which we find in them on the earth, yet we know from other circumstances that our feathers or our cork, if four times less dense and less compact in their ultimate particles than they are, or even much more than four times, would not give the slightest indication of this difference to the eye or to the touch. Whatever softness, or want of stiffness we now find in such things, would not be in the least increased. *Such are not the effects attendant upon a diminished density.* Lead in a fluid state is denser than when solid. Water is a great deal more dense than oak. The density of iron is nearly three times less than that of gold; yet, instead of iron being less stiff or less hard on that account, it is both stiffer and harder than gold. The denser substance is in many cases by a great deal the softer and more pliant and less strong of the two. It is the same if we compare glass and

lead. Glass is about five times less dense than lead; yet it is both harder and stiffer; harder, for it can scratch it; stiffer, for what will bend the lead will produce no effect at all upon a piece of glass of equal thickness. We see, then, that a body may lose its density without losing either its stiffness or its hardness. Nor does it lose anything of its nature: its ultimate particles undergo no chemical change. This we learn from the incessant and considerable alterations of density which take place in the mercury of the thermometer. We learn it from the bar of iron, which can be expanded by heat to a longer and a thicker bar, yet it is still iron. Even the bodies that expand most retain their chemical condition. Air dilates to any extent, but never takes the nature of anything but air. Water also, although highly expansible, never ceases to be water. When its ultimate particles are separated from one another to the enormous extent of 1728 times their ordinary state, even at that great distance (when they form what we call steam) they still cohere and retain their nature as minute particles of water. If we place a large vessel with

very little water in it, under the receiver of an air-pump, it will gradually expand (as the pressure of the air is removed) to ten, twenty, thirty times its original quantity, until it overflows the vessel, yet it will still have all the appearance to the senses of the condensed state. It is so with all the different substances upon Jupiter's surface. The nature of water, for instance, is as unaltered there as the nature of iron. It has, it is true, a density very different from that on the Earth's surface; so different, in fact, that an inhabitant of the Earth could not swim in it,—that a plank of our oak timber would not float in it, nor the water from our planet even mix with it, but, when thrown into it, sink to the bottom like so much sand. Yet no one has ever said that the water of the two planets is not the same. That of this earth, if taken to Jupiter's surface would, we know, in the course of a little time, expand, under the action of that planet's forces, to four times its original bulk, and thus assume the density of all the water there. But we have not, we repeat, the slightest reason for supposing—nor, indeed, has any one affected to suppose—that the chemical composition of the circumjovial waters differs in anything from

that of our own, or that any other elements, or in any other proportions than one atom of hydrogen to eight of oxygen, combine to produce them. And although, as we have said, a plank of our oak would sink like a stone if placed to float upon the dilated waters of that planet, yet we know from the same scientific and infallible source—almost, we might say, from the very same fact—that the oaken plank out of Jupiter's own forests will float upon his own waters, as our plank will float on ours. We know that in the tubular tissue of all his trees, the ultimate particles of nature are so arranged that they shall bear the same proportion in proximity and number (*i. e.* in buoyancy) to the ultimate particles of his waters as the atoms of our trees bear to the waters of the earth. Thus we see that it is not without good reason that no one has ever called in question the force of our analogy with regard to the existence of water upon Jupiter's surface. Indeed, one eminent writer has gone so far as lately to suggest that Jupiter might be all water. But, to say nothing else of this suggestion, it is inconsistent with our facts. We know that the water of this earth is four times less dense

than the average materials of the Earth itself, and we know that water on Jupiter is four times less dense than water here. The density of water on Jupiter is therefore (4 × 4) sixteen times less than the average density of our Earth. If Jupiter therefore were all water, he would be sixteen times less dense than the Earth. But we know, as has been shown, that his density is only four times less than ours.

Let us now proceed to his force of gravity. Every atom of matter on Jupiter's surface weighs nearly three times heavier than one of our atoms. This is thus calculated. He attracts at his centre with 333 times more force than our little globe does. But on account of his diameter, his surface is eleven times farther from the centre of attraction than ours is; and the force of gravity (as has been already explained) becomes weaker and weaker in proportion to the square of the distance from the centre. The force of gravity, therefore, on his surface is (11 × 11) 121 times less than upon ours, on account of the greater distance from the centre, and 333 times greater than ours, on account of his greater mass. That which gives

him *more* attractive force than we have, is thus nearly three times greater than that which gives him *less* of it. He attracts the atoms of his surface, therefore, and of everything on it, with nearly three times more force than the Earth does; and thus one of his atoms weighs nearly three of ours.

If these atoms were as closely set as ours, it is clear that a cubic inch of his lead would weigh three times as much as a cubic inch of ours; but, as they are not—as there are only a quarter of them in the same bulk—his cubic inch of lead does not weigh as much as ours. It weighs only three-quarters of ours; it is four times less substantial in the arrangement of its atoms, and weighs a quarter lighter. And so of all his other metals; his granite also, and his feathers —his seas and his atmosphere—all are not only less resisting and compact in their insensible and abstract relations—less dense, as it is called —than they are here, but also a little lighter. A man of the size that weighs on our planet 160lbs. would there weigh only 120lbs., which diminution of weight, if such a person were as strong as he is here, would give him a consider-

able advantage over us. But we have no reason to suppose that a muscular fibre and an osseous structure, with its atoms four times less compact than those of a strong man among us, could possibly yield equal strength, however much they might have this appearance. Some abatement must be made, though probably not to the full extent thus indicated; for the almost equal weight of Jupiter's materials to those of our earth, and the working with such, might well serve to give a little more development to the structure of the muscles, and of the tendons, and of the bones. And this holds with regard to all the other animal bodies as well as man's. They have neither exactly the same strength nor the same need of strength, as the animal bodies of the earth. The freer agricultural soil of Jupiter, and the lighter materials of his agricultural implements, as well as the nature, insensibly less substantial, of the plants and roots that he supplies for food, correspond well with what we know of the bones and the muscles of his peasants and his cattle. But, after all, this difference of strength is completely imperceptible, and nothing that can be supposed to interfere in the slightest

degree with the possibilities or even enjoyments of animal life; so far from it, in fact, as to make it doubtful whether, notwithstanding this difference, life is not rendered more enjoyable there than it is here. For see, we repeat, to what an extent the nature of things there conform themselves to this slight diminution of the animal powers. Every material requires the employment of less force for its manufacture; and this not from any outward or sensible deficiency in the strength and durability of the material, but from the arrangement of those hidden properties of matter which are completely inaccessible to sense, and discoverable only by the protracted attention of the mechanic or the philosopher. And every material is also considerably lighter than it is with us. Such a silver vase as that which here weighs four pounds, weighs but three in Jupiter; such a book as that which there weighs but twelve ounces, would here weigh sixteen; and the quantity of hay which here weighs twenty tons, weighs there only fifteen tons. This is all so very plain that it is not easy to account for the extraordinary mistakes that some have made with respect to

the weight of things in Jupiter, and that have naturally enough made them regard that planet as almost uninhabitable. The eminent writer to whom we have been obliged so often to refer, tells his readers that Jupiter's elephant weighs nearly as much as three of ours of the same size; whereas, any one can see by the simple calculation already made (and made also by this writer) that Jupiter's elephant is much lighter than ours; that if our elephant weighs four tons, that of the same size, which carries the lighter inhabitant of Jupiter, weighs only three. And besides the advantages which the density and gravity of materials afford to the less athletic frame of animals, nature has provided for it a quicker alternation of sleep and labour: for that world's night and day are but five hours each. Such differences are so manifestly the reverse of being inconsistent with the deductions of analogy in the case of Jupiter, as to make it unnecessary for us to point out to what an extent they strengthen them and confirm them.

On Saturn we find the incompactness of the atoms in material things twice as great in its amount as upon Jupiter; but how little per-

ceptible this is to sight or touch, we may judge from the incompactness of the atoms in iron. These are known to be much more than twice as incompact as the atoms of gold. It is, therefore, proper to bear in mind that, when we speak of the density of bodies, we speak of a property in them which, if it were not for the weight which ordinarily accompanies density, would be, in scarcely any case, discernible by the senses. Amber is ten times less dense than lead. There is ten times a greater distance between its atoms than between those of lead. The greater weight of the latter substance may guide us to this fact. But if the weight of the two substances were the same, or if the amber were the heavier of the two, should we not have wondered to have heard that amber is ten times less dense than lead? We see, then, that the density of bodies makes no difference whatever in their appearance to the senses except by their weight, and none at all of any other kind to the extent that, on first hearing of it, we are liable to imagine.

The density of the various substances upon Saturn's surface is usually described as being

twice that of those on Jupiter's, and eight times that of the same substances upon the earth. But this calculation, as well as that which represents Jupiter and all the other exterior planets as four times less dense than the earth, is founded upon an hypothesis which is by no means one of the *data* of astronomy, viz., that the matter of each planet extends equally to each planet's centre, instead of leaving the central region perfectly hollow; and that the rotation in all these planets being twice as rapid as in ours, and producing, therefore, a centrifugal force (2×2) four times as great as that of the earth, is attended with no other effect than that of diminishing the density of all the matter in the planet, instead of (what even at first sight seems so much more natural and consistent with astronomical data) merely enlarging that hollow region at the planet's centre. The matter or atoms of each planet must of course be distributed over the bulk, but this distribution is known not to be equal throughout. It is known, for instance, that the condensation at the centre is much less than in other parts of the sphere; that it is, to some extent, rendered so by the

dilating influence of the central heat; and that the outer strata of all are much less dense than those that lie immediately under them. There is, therefore, no ground for supposing an equal distribution of the materials; and if, as can easily be shown, the effect of the centrifugal force in distributing these materials—*i.e.* in driving them from the centre—is to enlarge proportionably the empty space in the region of the planet's axis, instead of mainly or only attenuating all the planet's substance, then the supposition of a different density for Jupiter and the planets beyond him is at an end. But we do not now enter upon this subject. We accept the ordinary hypothesis, clumsy and unphilosophical though it be, of a solid centre for all the planets, which hypothesis is supposed by some writers to make it physically impossible for the outer planets to have such strong and solid substances upon their surface as the earth has. It will be seen that with regard to this strength and solidity of the various substances, even in Saturn's case, these writers are completely mistaken, and we shall even give them a stronger case than they make for themselves.

For this purpose, as well as for the sake of round numbers, we shall speak of Saturn's density as being only one-tenth that of the earth instead of one-eighth. For his mass is estimated as 103 times greater than ours; and his diameter being nearly ten times greater, his bulk is ($10 \times 10 \times 10$) 1000 times greater than ours. His mass is, therefore, about ten times less than would have made an equal density—*i.e.*, his density is ten times less than ours; or, in other words, there is ten times more distance between his atoms than between ours, and therefore ten times fewer atoms in each of his substances than in the same substances upon the earth. And each atom of matter weighs exactly the same on Saturn as with us; for, though his mass is so much larger, and, therefore, so much more powerful than ours, his surface is much farther from the centre of attraction—ten times farther. The square of this being (10×10) 100, we find that, although he attracts with 100 times more force than we do, by reason of his greater mass, he attracts on his surface with 100 times less force, by reason of his great diameter. This results in a force of gravity, exercised at his surface upon every atom there, exactly equal to that exercised

on ours. In consequence of this coincidence, the different materials and objects on Saturn's surface are as much less heavy as they are less dense than those on ours; because there are ten times fewer atoms in the same bulk of any given substance, and, as we see, each atom weighs the same as ours. The same bulk, therefore, of the same substance, weighs ten times less, as a consequence of its having ten times fewer atoms in it.

The first reflection to be here made is that already so often insisted upon—that density and weight are *relative* properties of bodies—properties that result only from proportions or relations; and that so long as its *relations* are exactly and universally preserved, no real change can be effected in them at all. If all the materials and objects with which we are acquainted in this very dense planet of ours, were all at once to have their relative densities diminished to ten times less than that in which our planet now stands to the other planets of the system (which could as easily be effected by altering their densities as by altering ours), and if no exception were made in favour of any kind of object or material known, the effect would be

precisely the same as if the densities of things had continued as they were—the inhabitants would be conscious of no change; in fact, none would have taken place among the things themselves. The relations, in this respect of density, to other planets might be altered, but this could neither be perceivable to us, nor attended with any kind of inconvenience or discomfort: in short, with any kind of consequence to us whatever; and this is true of weight also. Just in the same way, if the humours of the human eye were all at once and everywhere so far altered from what they now are, as to enable us to see everything and everybody twenty times larger, or twenty times smaller, than we now do, all objects would in such a case be seen by us of the same relative dimensions as they are seen now, and the effect would be to us exactly the same as if no change of any kind had taken place. There would be neither discomfort nor inconvenience—not even astonishment; for we should be totally unconscious of a change. Or let us adopt the common error, and suppose ten times less dense to imply ten times less firm. This difference would be more than twice as

great as we find existing in the sandy and clayey soils that we have to deal with in our own planet; but, in Saturn, this comparatively loose, free soil (in his lighter lands not much firmer — let us say — when pulverized, than sawdust or powdered cork) would be all that could be managed with the slight implements to be had there, and by the slight bones and less compact muscles of the workmen, and all that could be required to grow the unsubstantial trees and vegetables adapted to the uses of such workmen. If the physical strength of man did not undergo a proportionate reduction; if it were, in such circumstances, as great as it is amidst our dense and heavy matter, the difference of density would then, indeed, be disproportionate and palpable. A man would be capable of doing ten times as much work as we are; he could leap ten times as high, walk ten times as far. His strength would, in fact, be ten times as great as ours; but we know that this would not be the case. A muscular tissue considerably less compact and robust in its atomic structure than ours, bone much more liable to be broken, if used with the same force as we use

ours, daily food much less substantial—to say nothing of the enervation consequent upon habitually working with materials considerably slighter and less intractable than ours—are portions of this hypothesis, in consequence of which Saturn's inhabitants, although as robust in their planet as we in ours, would find themselves fully ten times less so than we are, if they had to work with our materials, to live upon our food, and to bear the pressure, or inhale the oxygen, of our atmosphere. But, although this is so manifest, and although so much might, appropriately enough, be said for the equality of advantage in these respects upon both planets, even in the supposed case, yet it must be clear to the student of nature that it is no part of our task to show that Saturn's inhabitants are as free from inconveniences and incongruities of circumstance as ourselves. If they had a great deal more to contend with, in broken proportions of density or gravity, unknown to us, than in other respects those have to bear, who pant beneath our tropics, or seek their food upon the shores of our polar seas, there would be nothing even in this to justify us in disregarding the

analogy that the Great Maker of our planets has impressed upon them; or in concluding that, most probably, there are no inhabitants in the planetary system, except where they could subsist at the same advantage as we suppose that they do in the more temperate portions of our own globe. Instead, therefore, of enlarging upon and illustrating further the thorough equality in the conditions of density and gravity, between the inhabitants of Saturn and ourselves, under the above hypothesis, against those who imagine impediments in the way of this equality; and, instead of deviating still wider from our path, to mention all the reasons that suggest themselves to us for supposing that, in other respects, the accommodation for intellectual life upon Saturn would, even so, be superior to that upon the earth, we turn from these and all such considerations, to what must be looked upon as the true question presented to us by the great amount of difference in density that we detect between the materials of the two planets. This question is purely and simply as to the physical possibility of the various substances of our earth undergoing so great an

amount of dilatation, in the ultimate recesses of their nature, as that now in question—as that which is implied in the existence, upon Saturn's surface, of a bone, a feather, air, water, a muscular fibre, a rock, a metal, and all other such material things, and of their undergoing all this change in their insensible proportions without the destruction of their strength and stiffness, or of the chemical union of their atoms, and without the substances themselves becoming thereby either transmuted or dissolved. Such is the only question that is here at issue; and its importance is such that, at the risk of repeating myself upon some points, I shall crave the reader's patience while I add somewhat further to the explanations that have been already given in anticipation of it.

As proof that no sensible difference of strength, or stiffness, results from the ultimate particles of matter being ten times less close together in one substance than in another, and that any insensible difference of this kind that really does result from it, is much less than the thing itself would have led us to suppose, silicon, or flint, the main ingredient in our rocks, is seven or eight times less solid and less

compact, than gold—*i.e.*, its atoms are that much fewer—that much farther apart—than those of gold;—yet silicon is a strong, resisting, heavy, and substantial body, not at all what we should call unsolid or incompact. In the stoutest oak-timber these ultimate particles of matter are much more than twenty times farther from one another than in gold; yet "incompact" and "unsolid," it will readily be admitted, are very unsuitable terms to describe the condition (with respect to density) of the stoutest oak-timber. Such facts alone ought to be sufficient to arrest our attention. From this we at once see that Saturn's want of density does not imply that want of solidity and want of strength—that want of substance, in short—in the various objects upon his surface, which is ordinarily imagined by those who exaggerate to themselves, as so many do, what they consider the untoward consequences of Saturn's materials being nearly ten times less dense than those of the earth. And a little reflection will show us how this is—how so great a change in the condition of the atoms produces so small a result in the condition of the substance. If the atoms of bodies were at a perceptible distance

from one another, every doubling of this distance would, of course, be more and more perceptible. We should then easily be able to perceive by the eye, or touch, that iron is nearly three times less dense than gold; and it would be but natural to expect that if this expansion, even of the densest body, was carried to the extent of ten or twenty times, instead of thrice, there could no longer be a union of such distant atoms—much less a union and compactness like that which we find in our most solid timbers. But the distance at which the atoms of *all* bodies, even of feathers, are from one another is (as well as the atoms themselves) not only imperceptible, but, confessedly, inconceivably small—so small that even if it were increased a thousand-fold, we could no more see it than we could see a group of a thousand atoms, a million of which, it is admitted on all hands, would be too minute an object for our most powerful microscopes. It might, in fact, be excusable in unscientific people to entertain some misgivings, after such statements, as to whether there may be any distance at all between the atoms of bodies; but of this we have indisputable evidence in the fact that *all* bodies

are more or less compressible, and, what is not a little remarkable, indefinitely so. When the distance, then, between the ultimate particles of matter is so small as to be inconceivable, it can hardly be said to become less inconceivable when it is lessened or increased ten times. The change which takes place in these imperceptible distances, although it is very considerable, and such as materially affects the bulk of the whole object, remains necessarily as imperceptible *in itself* as the distances themselves are in which it takes place. Thus we not only see how so great a change can take place without its being in the slightest degree perceptible to the senses—and this in feathers as well as in gold—but we are led by thus analyzing the subject to see, beyond what we actually require, that the same change might be carried on to an almost indefinite extent without affording any chance of its becoming imperceptible to the senses. Without pursuing this second point, however, any further, we content ourselves with the first—viz., that the atoms of feathers, as well as of gold, might be drawn apart from one another ten times further than we now find them, without this

change in the atomic structures being perceptible to our senses, and without the ultimate particles, either of the feathers or of the gold, exhibiting the slightest disposition to relinquish their hold upon each other.

Another reflection will render the same thing still more evident—will render it, we repeat, still more evident—that the fifty-five elementary substances of our planet, and their compounds, are perfectly compatible with any amount of dilatation that can be produced, and are therefore exempt from all possibility of being dissolved, or destroyed, or commuted, by the amount of it on Saturn, although that is incomparably the greatest amount of dilatation supposed throughout our planetary system. It is known that compound substances depend upon the diffinitive proportions in which their elementary substances are combined; that this combination is a chemical one, and one therefore which cannot be dissolved without that chemical decomposition which no mere mechanical force can effect. The so-called simple bodies also—that is, those whose component substances have not yet been discovered, are regarded by the chemist as being in the same predicament, and as resulting from the

definite proportions in which other substances are combined to form them, although we neither yet know the proportions nor the substances. This combination is, of course, as in the case of compound substances, a chemical effect, and, like that, cannot be disturbed by any kind of mechanical action. When a mechanical power, therefore, such as the centrifugal force, or gravitation, or any other, is employed in the expansion of bodies, it is not upon the atoms that are chemically combined (called the "constituent atoms") that it acts, or could act, but upon the compound atoms (the "integrant atoms") that result from these, and into which we suppose the compound, or simple substance, to admit of being indefinitely divided. These, the mechanical force (or heat, when it acts as such), can separate one from another to any extent to which it is employed; the others it cannot separate at all; yet as long as these others cohere, and do so in their original definite proportions, the substance itself (be it feather or gold), however much mechanically dilated, must still subsist unaltered, either intrinsically in its chemical properties, or externally in its appear-

ance to the senses. To give an instance: water is composed of the two gaseous bodies—oxygen and hydrogen. The definite proportions in which these elements unite to form water are eight atoms of oxygen with one of hydrogen. These nine constituent atoms form one integrant atom of water. They cannot combine in any other proportions than eight to one. These proportions are therefore called "definite." If twelve atoms of oxygen be present with one of hydrogen, four of oxygen will remain over, uncombined, until another atom of hydrogen and four more of oxygen be added. They will then unite and form another compound, or integrant atom, which will unite with the first, not chemically, as oxygen does with hydrogen, but mechanically, as water does with water, increasing the quantity; and so on indefinitely. Not an atom, however, of the hydrogen will subsequently leave its first combination to unite with other oxygen, nor of the oxygen to unite with other hydrogen. Whatever breaks up the union of the oxygen and hydrogen, *i.e.*, of the constituent particles, destroys the water; the water ceases to exist. Whatever breaks up the union of the integrant particles with one another, only sepa-

rates one portion of the water from another. Whenever heat, or Saturn's rings, or a moon, or the sun, or the centrifugal force, or any other dilating agent, causes water to expand, it disturbs not the chemical union of the two gases. Its action is confined to the distance that exists between the integrant particles of the water. This distance it augments, and this is all in which it effects the smallest change. No amount, therefore, it is evident, of mechanical force—no enlargement of the spaces between the integrant particles—could ever effect the decomposition of these particles (had this been possible it must have occurred in the case of steam); and they, being thus compatible with any amount of dilatation, the substance itself, of which they are but parts, must be so likewise.

A doubt seems to have arisen to some minds as to whether a tenfold separation of the ultimate particles from one another might not produce the fusion of solid bodies. But this doubt is at once removed by the fact that several substances have their density increased by fusion, instead of being diminished by it, and *that* notwithstanding the ordinary expansive power of heat. Iron, for instance, when melted, is found to be denser than

when it is cold, instead of less dense; and ice is much less dense than after it is dissolved to water, as we may see by its floating upon water. Fusion, therefore, does not result from a want of density.

But further; increasing the distance between the integrant atoms is not the only way in which the density of substances can be diminished. That distance is as imperceptible to the senses, we have already observed, as the integrant atoms themselves between which it exists. That distance, therefore, is not what gives rise to what we call the pores of a substance. These are interstices between much larger portions of the substance, and are frequently obvious to the senses. They exist in solids only (not in liquids or gases), and more or less even in the densest of them. But it is especially in feathers, bones, cork, sponges, wood, the ordinary rocks, and such other lighter substances, that we most easily discern them. In such bodies, it is evidently more by the enlargement or multiplication of the cells or tubes that a diminution of density is effected than by any augmentation of the spaces between the integrant atoms; and this fact is entitled to much consideration in reference to our present subject. It might seem to

many very difficult to understand how the separation of the integrant atoms in a feather—in which they are already so much separated—could be carried to the same extent as in a metal, or keep pace with the exigencies of a planet in which this separation is ten times greater than it is here. But the cellular and tubular tissue of such bodies show us that nature is provided with a grand contrivance for such emergencies—a contrivance whereby we clearly see that the cohesive principle of the lightest solids, as well as their hardness and stiffness, could easily be sustained under even a much greater diminution of their density than that which they undergo upon the surface of the least dense planet in our system.

The Essayist who has lately pretended to "guess" and theorize with so much levity, and to such an extraordinary extent upon this subject, maintains that if his views are correct, Saturn (as well as Jupiter, Uranus, and Neptune) must be a sphere of water, in consequence of its great want of density. We need only observe that as Saturn's seas are more than eight times less dense than ours, that planet would, if it were all made of water, be more

than thirty-two times less dense than this earth, whereas no *data* represent it as more than about eight times less so.

Respecting the weight of things on Saturn, it is unnecessary to say much. People ordinarily find it more easy to adjust his weights than his densities to the immutable laws of those materials which analogy teaches us to believe existing in that planet as well as in all the others; and it is not unusual to regard the extreme lightness of things as even a greater advantage on the side of animal, vegetable, and intellectual life, than it necessarily is. It will suffice, therefore, to remark that weights and measures are things so completely arbitrary that our analogy offers us no guide to the proportions employed upon Saturn; and guessing or conjecturing (our readers will bear us witness) is no part of our present purpose. We can therefore only speak conditionally on such a point as this. If the inhabitants use weights in the same proportion to the things around them as we do, the human body there of the ordinary size among us, would weigh as here from about 150lbs. to about 200lbs. But if they employed weights taken from this sphere (which of course they do not), a

person of that size would weigh but from about twenty to twenty-five of such pounds, and everything else in the same proportion. The same sized loaf as weighs here four pounds, weighs there about eight of our ounces, or if the inhabitants have proportioned their weights upon the same principle as we have done—four of their pounds. In like manner the elephant that here weighs two tons, weighs there either two tons or five hundred weight, according to the planet that is supposed to supply the weights with which we weigh it.

Of the two more distant planets known to belong to our system—Uranus and Neptune—the masses and diameters are sufficiently ascertained to show us that their density is almost the same as Jupiter's and their force of gravity the same as ours. In Uranus the mass 15 divided by the bulk ($4 \times 4 \times 4$ rather more) 70, gives the density not quite $\frac{1}{4}$; and the same mass 15 divided by the square of the distance from the centre to the surface (4×4) 16, gives the force of gravity rather less than 1; all with reference to our earth. In Neptune the mass 20 divided by the bulk ($4\frac{1}{2} \times 4\frac{1}{2} \times 4\frac{1}{2}$) 90, gives the density a little less than $\frac{1}{4}$; and the mass 20, divided by $20\frac{1}{4}$, which is the square of the

semidiameter (*i. e.* of the distance from the surface to the centre), gives the force of gravity something less than 1; also with reference to the earth. This, after the explanations now given, has evidently nothing in it in the slightest degree inconsistent with the nature of the materials, of the bones, of the muscles, and of the plants, that analogy compels us to assign to these important worlds. A man weighing here 160 of our pounds, and in Jupiter 120 of them, weighs in Uranus, and in Neptune, only about 40 of such pounds. But if the inhabitants of Uranus and Neptune have adopted (as we have every reason to suppose they have) the same proportions in their weights and measures as we have done, or if their stature is about three feet greater than ours (which we have no reason to suppose it is), then in each of these worlds the weight of such a person is represented by 160lbs., just as it is here.

Thus, then, it appears that even with the received hypothesis (viz., that the increased centrifugal force of the exterior planets *dilates* the matter of each planet instead of merely *transferring* it farther from the centre towards the circumference), no reason can be shown for supposing that the organic structures and inor-

ganic materials with which we are acquainted, cannot subsist upon the surfaces of the exterior as well as of the interior planets, and further that it is contrary to astronomical facts to suppose that Jupiter, or any of the planets beyond him, could consist of water or vapour, either wholly or to any considerable extent, and contrary also to astronomical facts to suppose that things upon Jupiter's surface are heavier than upon the earth.

SECT. II.—*Of the Solar Light and Heat on the Surfaces of the Planets.*

Let us now turn our attention to the information which science affords us respecting the condition of the neighbouring worlds in the important particulars of solar light and solar heat. It will be seen that in these respects they are all very nearly upon a par (even Neptune having quite as much as we have), and that, not improbably, further scientific research, or a more diligent use than that here made of the facts already ascertained, may enable us to pronounce that they are all entirely so.

It is evident, however, that, although the

analogy between the planets leaves us no alternative but to conclude that they are all inhabited by intellectual creatures like ourselves, if such creatures can at all manage to subsist upon them, yet it does not by any means oblige us to suppose that life is as enjoyable upon all of them —or enjoyable in the same way upon all—as it is in the temperate zone of any one of them. If we know that it is so, it is from another source. Our analogy supplies no such knowledge; nor does it require it. It is not limited to the phenomena of a temperate zone. The inhabitant of our tropics, who has heard of the cold of a northern winter, will look upon the little planets nearer the sun as more likely to be inhabited than the larger and more distant ones; and the Laplander who has once made a journey to the tropics, and whose months of darkness cause very little inconvenience to his daily occupations, will be very apt to think of Neptune as a more habitable world than Mercury; especially if the central heat of so large a planet can be shown not to be intolerable upon its surface. We of the temperate zone are but too ready to fall into the same error, and to think that neither the outer nor the inner planets are likely to be

inhabited, because we consider them all less habitable than the zone in which we live upon our own planet. All such speculators upon the improbability of analogical truth might, surely, easily convince themselves of the bias and misconception by which they are much more misled than by the statistical inadvertencies under which they seem to labour. Even if things were as they suppose—if incessant moonlight and incessant ice were sources of extreme animal and moral suffering, and could be shown to exist in any of the planets, yet unless we are to believe such things to have the effect of destroying the human species either by destroying their food or by disabling their faculties, it is evident that the mere suffering that they are supposed to occasion, does not in any way interfere with our analogy, which only tends to establish the original stocking of the planets with human beings, whether upon the most improbable principle of self-development lately suggested, or upon the received and far more natural one of interposed creation. And the same remark applies to the almost incessant daylight of Mercury, and Venus, and Mars, and to the torrid zone supposed to be universal upon Mercury.

If these cannot be shown to derange the physiological or intellectual faculties, the mere discomforts that attend them, or miseries, if such do attend them, would constitute no objection to the analogy we are defending. Supposing the globes of our system to have their heat and light as excessive or deficient as is generally but most groundlessly imagined, we do not find these extremes so great in any of them as to lead us to conclude that even the human species might not live very well in all. "Man is found," we read in a popular work, "under the scorching sun and amid the arid plains of Africa, as well as in the frost-bound regions of Spitzbergen; and he is found to live and thrive under these different extremes. The Esquimaux and the Canadian savage will prosecute their usual employments of the chase in a temperature where mercury freezes into a solid mass (39° below Zero), and where even brandy congeals to ice in apartments containing fires; while the African negro, again, feels quite at his ease in a burning climate, where the thermometer in the shade ranges from 90° to 100° and upwards." We see in such statements, of how much man's animal life is capable, and have therefore in them

the true terms of the question at issue:—If Neptune really had always less sunshine on his surface than they have in Lapland or Spitzbergen during winter, would he have too little for the chemical and physiological purposes that the sun's light subserves in the animal economy? If his surface glows with subterrene fires, or that of Mercury stretches out in arid sands beneath a scorching sun, is the heat in the most temperate portions of either planet so much greater than that of the African tropics that even a race of negroes must perish under it? Or if, on the contrary, the extreme cold in the warmest zone of Neptune is greater than that of Spitzbergen and North Canada, is it so much greater that, even with the aid of migrations, the Esquimaux and the Canadian savage could not live there or find food there? The utmost that we are called upon to do in support of our analogy, is to show that man's animal life is physically possible with the light and heat of some portion of each planet; and this who can declare to be absolutely and physically impossible, when he reflects upon the greater central heat resulting from the greater material pressure of the larger planets,—upon the occasional light of a solitary moon during

the sun's absence for several months from the polar regions of our planet—and upon the effect of the sun's continued absence from Mercury's polar regions during some portion of his year, and of his oblique rays there during the rest of it? Instead of enlarging upon these points, which will approve themselves abundantly convincing to most minds that are in earnest with the subject, and which really meet all the objections that can be raised to our analogy upon the grounds of physical impossibility, we advance to a consideration of those astronomical facts from which we can learn with something like mathematical exactness that the amount of solar light and solar heat enjoyed by the inhabitants of each of the other planets is very little, if at all, different from that upon the surface of our own.

The average amount of the solar heat and light upon the surface of each planet depends wholly upon the density and extent of the media through which they pass. The varieties in the actual amount, which are greater upon some planets than upon others, arise from various

causes, such as the planet's diurnal rotation, its size, the inclination of its axis to the ecliptic, and the diameter of its orbit. When the days and nights are twice as long in one planet as in another, the days amass more heat and the nights more cold than where they are shorter. In Neptune, for instance, the days and nights have not even so much as half the length ours have, being five hours instead of twelve. The temperature is therefore more steady. When one planet's diameter is twice as great as that of another, the extent and density of the media being the same, the shadow of the smaller planet in its own atmosphere at night is less extensive, and therefore less dark; for the solar rays which then shoot up along the planet's sides towards the darkened hemisphere traverse only half the lengths which they traverse in the case of the larger planet, and therefore give a reflected light of four times the strength and four times the duration. This effect is still further increased when the atmosphere is more dense or more extended. Thus in Mars they can read all night by twilight. A planet which has no inclination of its axis to its path, has, *cæteris paribus*, no more

cold, in any given latitude, at one part of the year (or orbit) than at another. This is the case, or nearly so, in Neptune, Uranus, and Jupiter, where in our latitude the inhabitants enjoy a perpetual spring—and therefore, as far as this cause is concerned, a higher temperature than our thermometer marks in spring. Where the axis is inclined, if the orbit is great, the extremes of heat and cold will be proportionably so;—in other words, where there are summer and winter in a planet, if each lasts twice or twenty times longer than in another planet, the winter will be colder and the summer hotter in proportion. This result is obviated in Saturn by the action of his rings; but Mercury's summers, as far as the cause now indicated is concerned, are four or five times less hot than ours. All these, however, are mere varieties in the degree of light and heat at different times or places upon the same planet,—varieties to which every planet is more or less subject, and which have little effect upon the average amount. Such matters, therefore, do not properly belong to the present investigation. If the average is the same, or nearly the same, on all, then every

planet has at some place or at some time as much of the solar heat and light as the rest: and this is all that we require to know. Neither is the physiological capacity for light in the inanimate world less to be considered, as some erroneously seem to think it is, than in the animate. It is in fact in this sense alone that our investigation has any interest. In what quantity the solar light is seen by the inhabitants of any given planet—even of our own,—what quantity of it they are conscious of, and use in ordinary life, is quite another question, and an extremely difficult one, the answer to which must vary in the case of each animal, according to the sensibility of the retina and the size of the pupil. When under complete stimulation of the retina by the solar rays, an animal is conscious of the fullest sunshine, however small a quantity of light is sufficient to effect this stimulation; and in some animals, even among us, we see that much less suffices than in others. When the retina is but very partially stimulated, what the eye perceives is twilight, whether this proceeds from the light outside the eye being insufficient, or from the pupil being too small, even when

most expanded, to admit a sufficient quantity of it, or merely from the difficulty with which the retina itself is acted upon by the light admitted to it; and there are no means of knowing what proportion the solar power bears to the light so perceived, for this light depends much more upon the nature of the retina and upon the size of the pupil than upon the amount of that power. Twilight therefore could be rendered excessive sunshine, merely by increasing the sensibility of the retina or the diameter of the fully expanded pupil; and the most dazzling rays could be reduced to twilight by diminishing this sensibility, or by diminishing this diameter; and all this without the slightest change in the amount of the solar power. But the real question of interest to us at present is not to inquire into the visive powers of different eyes, but to ascertain what is the average proportion of solar heat and light that is to be met with upon the surfaces of the different planets, for the various chemical and physiological purposes to be effected there, and to show how completely all the planets resemble each other in this respect. We have said that this proportion depends upon the

density and extent of the two media through which the sun's rays pass. These media are, 1, the ethereal medium existing between the sun and the atmospheres of the planets; and, 2, each planet's own atmosphere. It will be seen, however, after the removal of four errors, that it depends mainly upon each planet's own atmosphere, and to but a very small extent, if at all, upon the ethereal medium.

FIRST ERROR.

The great law of light is that, in passing through a uniform medium, it decreases inversely as the square of the distance—that is, it decreases not merely (as one might imagine) in proportion as the distance over which it travels augments, but as the square of this distance augments, which is a very much more rapid rate of diminution. Thus Neptune, being thirty times farther from the sun than we are, and the square of 30 being 900, the light outside Neptune's atmosphere is reduced 900 times more than it is reduced outside our own; or, in other words, the reduction of the solar light which takes place in its passage from the sun to our

orbit (great or small as that reduction may be) is 900 times less than the reduction which takes place between the sun and Neptune; but, though that reduction is thus quadrupled at every doubling of the distance, it is evident that the light is not reduced to one quarter of its amount by the operation, nor perhaps, unless the medium be a dense one, perceptibly reduced at all. The light outside Neptune's atmosphere is nevertheless said by popular writers to be 900 times feebler than the light outside our own; and Neptune's atmosphere being equal to ours in its effect upon the light that passes through it, the light within it, is therefore (in the same inaccurate terms) 900 times feebler than that within ours. Such however is merely the popular expression of the scientific fact just stated. The natural interpretation of such language indeed is that the sunshine upon Neptune's surface is equal to the effect of about eight hundred and ninety of our full moons all shining at once; for it has been calculated by Wollaston and other eminent writers on photometry that our brightest sunshine is equal to the light of 801,072 moons, and it is the com-

mon supposition that the light on Neptune's surface is 900 times less than that on ours. His share therefore of our brightest sunshine would in this way be equivalent to the light of 890 moons. But this view of the matter, although yielding more light than is generally supposed, is a complete misinterpretation of the great optical law above given. It is not at all in this sense that the solar light on Neptune's surface is said, by scientific men, to be 900 times feebler than—more reduced than—ours. Such a construction of the terms is a mere misconception of the unlearned, dissipated at once by the slightest science, although adopted apparently, as an inference from the true one, by the able writer of the Essay "Of the Plurality of Worlds," in aid, as it were, of what he considers the best scriptural theory of the universe.

SECOND ERROR.

If the solar rays had to force their way 3000 million miles out to Neptune from the sun, through a medium as dense as our atmosphere, we can see at once that this might easily reduce the solar light and heat upon Neptune to 900

times less than we have. Or even if we were not quite so unreasonable—if, when we speak of Neptune as being thirty times farther from the sun than we are, we understood (as all writers seem inadvertently to do) that the solar rays had to pass through thirty times as much atmosphere as they do in their passage to the surface of our earth, in this case also it would be easy to believe that 900 times less than our ordinary sunshine, would be all that could possibly ever reach the surface of that remote planet. But since, instead of this, the ethereal medium traversed by the solar light in its passage to Neptune's atmosphere, is, and is admitted on all hands to be, excessively attenuated and rare, so much so, in fact, that it has not unfrequently been regarded as a vacuum—and since the solar rays pass through no other atmosphere except Neptune's in their course to Neptune's surface from the sun, there is no reason for supposing (as people do) that the solar light becomes absorbed, to any perceptible degree, in that rare medium—no reason for supposing that it is much more feeble, or even perceptibly so, outside Neptune's atmosphere than outside Mercury's,—no reason, in

fact, for supposing that it undergoes any other modification of much importance, in its progress to a planet's surface, than merely that which is effected by each planet's own atmosphere; distance alone, as is admitted by all writers upon optics, having so completely nothing to do with the diminution of light, that if all the medium they suppose between Neptune and the sun were compressed into the space between the sun and Mercury, the light at Mercury would be exactly as much diminished as it is now, according to them, at Neptune.

Nor, these facts being once known, can there be any difficulty in seeing that when we speak of Neptune's light as being 900 times less than ours, we only mean 900 times more reduced from the original amount of the solar light at the sun than ours is, although we have no notion whatever, and can have no notion whatever, of what that reduction amounts to, even in our own case, nor whether it amounts to anything at all;—there can, we repeat, be no difficulty in seeing that by such expressions, we only compare the light outside Neptune's atmosphere with that outside our own,

and that we could not possibly mean anything so preposterous as saying that the ethereal medium reduces the solar light by the time it reaches the region outside Neptune's atmosphere to 900 times less than our own atmosphere has the power of reducing it (*i.e.*, to 900 times less than the light upon our surface), for we have not the means of instituting any such comparison; nor could we with more reason be supposed to mean that even Neptune's atmosphere could effect a reduction of this kind,—that Neptune's atmosphere could by any possibility produce a light upon his surface 900 times less than our atmosphere produces upon ours; and still less, if possible, could we mean that Neptune's atmosphere produces a light at its base 900 times less than the light that is outside it, or 900 times less than the light that is outside ours. The proof that we can mean none of these things, by the expression we advert to, is that we have no materials of any kind for forming any judgment whatever upon such matters. All that the expression means is, that, whatever reduction (if any) is effected in the solar light before it impinges

upon our atmosphere, a reduction amounting to 900 times as much is effected in it before it impinges on the atmosphere of Neptune. What that reduction is (as I have just said) between our atmosphere and the sun we do not and cannot know. It depends upon the tenuity of the ether through which the light has to pass. If the ether were dense, the reduction would be considerable; if excessively rare, the reduction would be so slight that even 900 times more of it (were not this proportion itself in this case an error) would still be very inconsiderable; or if, as some think, there be no ether in space, and the intervals between the sun and the planets be a vacuum, then no reduction at all takes place between us and the sun, and, therefore, none at even thirty times our distance.

As a good deal of the confusion and miscalculation respecting Planetary Life has arisen from the popular error now exposed, respecting the interplanetary medium, it may not be unadvisable to recapitulate the facts in the following form. Let us for an instant suppose the space between the planets and the sun to be a

perfect vacuum. In that case the solar rays undergo no diminution in their passage from the sun to Neptune. They present themselves outside Neptune's atmosphere in as much force as outside that of Mercury. The only diminution that they undergo before they reach the solid surfaces of the respective planets, in the case that we are supposing, is that which is effected by each planet's own atmosphere; and the atmospheres of all the planets being of nearly equal minuent power, the light at their respective bases is nearly equal. The law of light does not apply to this vacuum at all. Neptune is still thirty times further from the sun than we are, but we cannot say that the light outside Neptune is 900 times less than that outside the earth; still less, if possible, can we say that the light at the base of Neptune's atmosphere is 900 times less than that at the base of the earth's atmosphere. Now, things being in this state, let us suppose an extremely rarefied fluid to be diffused throughout the interplanetary spaces, and their vacuum to be thus destroyed. It has been calculated that a single cubic foot of our ordinary air could produce this effect—could, if introduced into a

vacuum of that extent, expand sufficiently to fill the whole solar system. Let us then suppose this done, and the space between the sun and the orbit of the most distant planet all uniformly filled with the highly rarefied medium thus produced. It is evident that the law of light would again immediately apply. The diminution of light, indeed, even as far from the sun as Neptune is, would in so thin a medium be incalculably small. But there would be some diminution. Even in that thin medium, if it were uniform, light would decrease inversely as the square of the distance, and as Neptune is thirty times further from the sun than we are, the diminution would be 900 times greater outside his atmosphere than it would be outside ours; or, as the thing is ordinarily though improperly expressed, his light would be 900 times less than ours. It is evident, however, that the diminution of the solar light between the sun and the earth's orbit would, in this case be unimaginably small; so much so, that the 900 times greater diminution that would gradually have been effected in the solar light by the time it reached Neptune's orbit, would be still un-

imaginably small, — would be still much too small to make an appreciable difference between the solar light at our orbit and the solar light at Neptune's. And if we compare the solar light on the surfaces of these two planets after the further but exceedingly great diminution effected in it by their respective atmospheres, we shall of course see here also no appreciable—no imaginable difference that can be attributed to Neptune's distance from the sun, and we shall see at once the great error that we commit in calling the light on Neptune's surface 900 times less than the light on ours, merely because the light outside his atmosphere can in a vague, loose sense be spoken of as 900 times less than that outside ours; and we also see that even when it is applied to light outside the respective atmospheres, it does not indicate any difference that we can appreciate or almost imagine, but only means that the minute difference between the two amounts of light is supposed to be still more minutely divided into 900 parts conformably to their different distances from the sun.

Now, what we have here put as a supposition

is little different from the fact. The interplanetary spaces are occupied by an ether so rare and subtle, that (as we have said) scientific men regard them either as a vacuum, or as tantamount to a vacuum,—so rare that it offers not the slightest resistance imaginable to the extremely rapid movement of the planets, although the velocity of these movements is so great that it could only be possible in a medium 250 million times less dense than the air we live in. The calculation is thus obtained:—The velocity of the planetary movements is so great that, according to Sir Isaac Newton, if the medium in which they are performed were as dense as the highest stratum of our air, the amount of resistance offered to this velocity by that thin medium, would be the same as if they were performed in an atmosphere of molten gold. To place these movements, then, at the same advantage in space as our ordinary rapid movements are at, in ordinary air, we must assign them a medium as much less dense than our ordinary air as the highest stratum of our air is less dense than gold. Now, gold is nineteen times denser than water, and water 840 times denser than dense air, and dense

air 16,000 times denser than the air fifty miles high (*i.e.* the usual height attributed to the atmosphere of our planet). These numbers multiplied into one another ($19 \times 840 \times 16,000$) give gold as 250 million times denser than the highest stratum of the air, and give, therefore, a medium 250 million times thinner than our ordinary air as indispensable to place the planets' movements at the same advantage as express trains, for instance, are at in our atmosphere. Those who wish to test this estimate by another from a different source, may do so by calculating the condensation of ether effected by the attractive force of the sun at the different distances of the different planets; a calculation which affords a somewhat similar result. "It has been computed," says one writer, "that a cubic inch of the air we breathe would be so much rarefied at the height of 500 miles that it would fill a sphere equal in diameter to the orbit of Saturn." "The air, in proceeding upwards," says another, "is rarefied in such a manner that a sphere of that air which is nearest the earth, but of one inch diameter, if dilated to an equal rarefaction with that of the air at the height of ten semi-

diameters of the earth (40,000 miles) would fill up more space than is contained in the whole heavens on this side the fixed stars. And it likewise appears that the moon does not move in a perfectly free and unresisting medium, although the air at a height equal to her distance is so many millions of millions of times thinner than at the earth's surface, that it cannot resist her motion so as to be sensible in many ages." (Ferguson's Astronomy.) Thus, then, there is nothing, or next to nothing, to diminish the original amount of the solar light in its long transit to the most distant planets; for, as has been already observed, there is not upon record, any attempt—none has even been made by the Essayist—to make it appear that light could be absorbed by mere distance, or, in other words, that however much the proportion of light depends upon the proportion of medium traversed, the absolute amount of light itself can depend upon anything else but the absolute density of that medium.

THIRD ERROR.

The most perplexed portion however of the whole of this matter respecting the illumina-

tion of the planets is that arising from the confusion attendant upon the popular expression of the law that light and heat are inversely as the square of the distance; and that writer of great learning and eminence, to whose astronomical misconceptions we have had occasion already so often to advert, appears to have been completely involved in this confusion. He was of course aware that when Neptune was said to have 900 times less light than we have, the sense in which these words were popularly understood, was not that intended by the scientific; but as he nevertheless puts this sense forward as unobjectionable, we must, in justice to him, suppose that he at least infers its truth, as one or two less sagacious writers seem to do, from the true sense of the same terms, and that he labours under the impression that the proportion which exists between the successive reductions effected at each distance in the light emitted by a luminous body, exists also between the different amounts of light that remain at these different distances after each reduction. When, for instance, a given light is reduced at one distance by 900 times as much

as it is reduced at another, and the reduction at one distance is thus 900 times greater than at another, this writer supposes that the given light itself is consequently 900 times less at the one distance than at the other; which it evidently is not. If it were—if the principle which this ingenious speculator thus vindicates were true, light would decrease as rapidly in the thinnest as in the thickest medium; and the interplanetary medium itself would be of such a peculiar, and, we may add, extraordinary, nature, that any given length of it, could reduce any given amount of the solar light to exactly one-fourth of its force and brightness.

An illustration will perhaps help to exhibit the mistake we speak of:—Suppose a million lamps employed to illuminate an immense hall, and suppose one of them removed; the whole illumination is thereby rendered $\frac{1}{1,000,000}$ less than it was at first, and the fraction to which it is thus reduced is $\frac{999,999}{1,000,000}$. Suppose then we put back this lamp, and take away 900 lamps out of the hall *i. e.* 900 times as much as was removed in the first instance. The whole light of the hall is now $\frac{900}{1,000,000}$ less than it was originally;

it is now therefore $\frac{999,100}{1,000,000}$ of what it was originally. The reduction of light made is 900 times the original reduction; but the light that results is not 900 times less than the original light, nor than the light that resulted from the original reduction. It is not even reduced to one-tenth of it, nor to one-half of it, nor to three-fourths of it, nor is it in fact perceptibly reduced at all. Thus the amounts of reduction which light undergoes at different distances, bear no proportion whatever to the amount of light upon which the reduction has been effected, but only a proportion to one another. And so also the light at Neptune's orbit being supposed (as it will presently be seen, it erroneously is) to be less than that at ours, by 900 times a greater reduction than that which takes place between the sun and ours, does not make the light at Neptune's orbit 900 times less than the light at ours; nor does it afford us any data for forming an estimate of the proportion between the amount of light at these two orbits. It does not even enable us to see that the difference between them would be appreciable to the senses.

What this proportion is—what proportion the light at the sun's surface bears to the light at Neptune's orbit, or to that at ours, or to that at the orbit of any other planet, we do not know with much precision. We only know from the extreme tenuity of the ethereal medium, that the diminution in any case is inconceivably small, inasmuch as we know that it only keeps pace with the multiplication of a medium that is inconceivably rare. We may however even *see* that this is the case, by a comparison of the different discs, due allowance being made for the double distance in the case of the exterior planets. The most obvious clue indeed which we possess to the proportion in question, as well as to the truth of all the present reasoning, is the different amount of illumination which we find upon the discs of the different planets, although the difficulty and supposed insecurity of the measurement have caused this source of information to be neglected. In the absence, however, of any positive photometric statistics upon the subject, we shall merely observe that there is nothing in what we see upon the planets' discs, or know of the ethereal medium, to lead

us to suppose that the solar light at our orbit or even at Neptune's, has undergone any such reduction from what it is in the neighbourhood of the Sun, as it would be possible for the keenest eye to discern, when unassisted by a photometer, if, even thus assisted, it were possible for the keenest eye to discern it; the misconception which has circulated upon this point, having mainly resulted from the supposition already alluded to, that the interplanetary medium was as dense as our atmosphere, whereas, at a low calculation it is 250 million times less so; which brings the light outside Neptune's atmosphere that much nearer to equality with the light outside the sun's atmosphere than the ordinary supposition does; and this, even if the medium we speak of were uniform.

FOURTH ERROR.

But the ether of space, if it exist at all, is known not to be a uniform medium. This is one of the points that require distinct and exact attention. Either the ethereal medium exists or it does not. If it does not exist, if all is vacuum in space, then the solar force at Nep-

tune's orbit is as great as at ours. If, on the other hand, it exists, it is so thin that the accumulation of its effects upon the planetary movements during all the ages of astronomical observation, is imperceptible. The reduction of stellar light proves, it may be observed, both its existence and its extreme tenuity; yet the main reason that astronomers now assign for supposing this medium is the contraction which we observe taking place in the orbit of Encke's comet. Professor Airy says that he considers the existence of the ethereal medium "perfectly established by the reasoning in Encke's Memoir;"—Sir John Herschel, that, "no other mode of accounting for the phenomenon in question appearing, this medium is the solution proposed by Encke, and generally received;"—and Dr. Nichol, that "after vainly searching for some other cause, inquirers are nearly unanimous in referring this extraordinary and hitherto unparalleled change (the contraction of a comet's orbit) to a resisting medium, or ether, occupying the planetary spaces." It is not impossible that light alone may be medium sufficient to account for all the effects

observable in the orbit of this comet; but as the ordinary impression is that stated, it becomes necessary to point out that the ethereal medium supposed, produces much less effect upon Neptune's light than even one might anticipate from so thin a substance, and this is easily shown; for the medium is subject to the sun's attraction—a force which, like light itself, and other physical forces, diminishes inversely as the square of the distance.

The medium is therefore more dense near the sun's surface than at Neptune; and as Neptune is thirty times farther from the sun than we are, the density of this medium is 900 times more reduced in his orbit than in ours. Here is a most important consideration that has been wholly ignored by the learned Essayist. Although the diminution of the solar light goes on after it passes our orbit, it does so in the contrary ratio from that which obtains in a uniform medium, and reaches our orbit also from the sun in the same contrary ratio. In other words, the solar force loses less and less of its intensity, as we proceed outwards from the sun, instead of more and more, as is

the case in a uniform medium. Its diminution decreases, instead of increasing, in proportion to the square of the distance. So that at Neptune's orbit the density of this medium being 900 times more reduced than it is at ours, and light being inversely as the square of the density (just as it is with regard to the square of the distance), the solar force decreases at Neptune's orbit (900 × 900) 810,000 times less in any given space than at ours. At Uranus, which is nineteen times farther from the centre of attraction than the earth, the density of the highly rarefied medium we are considering is (19 × 19) 360 times more reduced than where we are. Saturn is a little more than nine times farther from the sun than we are. The density at his distance from the sun, is therefore ninety times less in this point of reduction than at ours, and the diminution of light at the earth (90 × 90) 8100 times greater than that taking place at Saturn. Jupiter, being five times farther from the sun's centre than we are, the ether of his orbit is twenty-five times less dense in proportion than that of ours, and the diminution of light there (25 × 25) 625 times less

considerable than here. Our orbit in like manner being nearly three times farther from the sun's centre than that of Mercury's, our ethereal density is seven times less altered than his, and the diminution of light at his orbit forty-nine times greater than what takes place at ours.

By pursuing this calculation, it may be seen that the whole reduction of the ethereal density between the Earth and Neptune, amounts to only about one-third of that between the earth and the sun, and that therefore the whole reduction of light between that planet and the earth, is only one-ninth of that between the sun and the earth; in other words, that we experience only one-ninth less of the extremely small diminution of light caused by the ethereal medium, than Neptune does;—a fraction which varies, of course, according as the planet substituted for ours in the calculation is farther from or nearer to the sun than ours. It is evident, then, that the ethereal medium being so rare between the sun and the earth as not to impede the movements of Mercury or Venus, the diminution of the solar rays, in that space,

would, even if the medium were uniform, be so incalculably minute as not to be perceptible to the senses. The density of the medium, however, in that space not being uniform, but decreasing so rapidly as is implied in the square of the distance, the diminution of light at our orbit is less than in the orbits of Mercury and Venus, and therefore still more evidently, such as the sense could not appreciate; and the diminution of light between our orbit and the sun, being thus extremely small, a further diminution amounting to only one-ninth of this, constitutes a difference still less in any way appreciable; and this is the amount of the diminution between us and Neptune's orbit.

It is evident, also, that as there is no appreciable difference between the force of the solar rays outside Neptune's atmosphere and that outside ours, there is none in the case of any of the other planets.

Thus far we have been occupied with that common medium through which all the light of all the planets equally passes in going from the sun to them. It remains that we should

now speak of the medium peculiar to each planet, and of the proportionate diminution of the solar rays in passing through them. This, however, need not detain us long.

From the chemical and astronomical facts connected with the density and force of gravity upon the different planets, as explained in Part II. sect. 1, we conclude that all the planets have the same materials, although from their distance we have not yet been able to see the materials of any except our own; just as we conclude that there is some water in all the planets, although there is but one in which we see it; or just as we conclude that all the planetoids rotate upon their axis, although we can scarcely discover this rotation in even one of them. From the astronomical and optical principles exhibited in the foregoing part of the present section, we learn (what analogy alone might have taught us) that the solar force is the same at one planet's orbit as at another's; and from the ordinary principles of inductive science we learn that its action produces the same effects upon Neptune as upon Mercury, and extracts therefore from each square foot of surface in each of all the

planets, the same mass (or weight) of atmosphere, *i. e.* of oxygen, nitrogen, carbonic acid, and water, as it does on our own. In other words, we learn by induction that the atmospheric pressure is the same upon all the planets,—the *mass* or the *weight* of that peculiar matter the same upon every square foot of every planet. This also, analogy alone might have taught us. Now, except upon Jupiter, Mars, and Mercury, we find the force of gravity so nearly the same upon all the planets, that we may speak of it as the same. The same height of atmosphere, therefore, upon all except these three will, *cæteris paribus*, give the same weight; but Jupiter's matter being nearly three times heavier than ours, his atmosphere would thereby be reduced to onlyone-third the height of ours: while the atoms or matter of Mars being nearly three times lighter than ours, his atmosphere must be three times higher than ours to give the same weight upon each square foot; and Mercury's atmosphere nearly twice as high as ours, upon the same principle, his atoms being only half the weight of ours. Again, it has been shown in a former part of this Treatise, that Mercury's

atmosphere is twice as dense as ours is,—that the atmospheres of Venus and Mars are nearly the same in this respect as ours, that those of Neptune, Uranus, and Jupiter are each of them four times less dense than ours, and that Saturn's is about half as dense as Jupiter's. To have the atoms of their respective atmospheres dilated and condensed in these proportions, the heights of these atmospheres undergo alterations. That of Neptune is expanded to twice the height of ours; so also that of Uranus. That of Saturn is twice as high as Neptune's—about four times as high as ours, owing to the augmentation which his centrifugal force receives from the attractive action of his rings. Jupiter's atmosphere, which, in consequence of his force of gravity, would be (as has been said) but about one-third as high as ours, becomes expanded by the joint effects of his density and force of gravity, to about two-thirds the height of the earth's atmosphere. The atmosphere of Mars having the same density as ours, has only the height derived from the force of gravity on that planet—viz., it is nearly three times higher than ours; and the atmosphere of Mercury being

twice as dense as ours, shrinks into a quarter the height derived from its force of gravity in order to attain this density with the same weight of matter, *i. e.*, it becomes half the height of ours.

The effect of these atmospheric differences upon the quantity of heat and daylight enjoyed by the inhabitants of the different planets is very unimportant, if it amounts to anything at all. It has been already observed that light and heat diminish by the square of the density as well as by the square of the distance; in other words, they diminish by the square of the distance in the same density, and by the square of the density in the same distance. Thus, except Jupiter, none of the planets derive any considerable change in the amount of their daylight from the changes of density explained in the foregoing observations. For, though Neptune's diminished density ought to give him sixteen times more light upon his surface than the earth has upon hers, yet his atmosphere, being twice as high, and thus presenting a greater distance for the light to traverse, the light, thence derived, amounts to but one half of this.

The same result also holds in the cases of Uranus and Saturn. In the case of Mars the light is equal to ours by density, and (3×3) nine times less by height. In that of Mercury the density is doubled; but the distance that light has to travel through Mercury's atmosphere being but half what it is with us, the amount of light which reaches the surface is, as far as these causes are concerned, exactly as much as if its atmosphere resembled ours.

In Jupiter's case, the atmosphere is four times less dense than ours, and only two-thirds as high. In consequence of which about twenty-four times more light would reach his inhabitants from this diminished density than reaches us;—an inequality, however, from this source, which is fully removed both in this case and in that of the other planets larger than ours, by the smaller proportion that subsists between the diameter of these planets and the height of their respective atmospheres than subsists between our diameter and the height of our atmosphere; which smaller proportion also renders a greater quantity of moonlight necessary for the larger planets. But these are unimportant

details, which would now lead us too far. The great scientific fact is evident, that the inhabitants of all the planets farther from the sun than we are, enjoy as much of the solar light and heat as we do, and that the inhabitants of the planets nearer to the sun than we are, have no more of this light and heat than we have. All the ordinary misgivings therefore upon this subject are groundless.

To recapitulate the contents of this section: it is matter of scientific certainty—

1. That Neptune's orbit being thirty times farther from the sun than ours, does not make the solar heat and light outside his atmosphere $\frac{1}{900}$ of that outside ours; and that Mercury's being nearly three times nearer to the sun than we are, does not make this light and heat outside his atmosphere seven times greater than that outside ours.

2. That the difference between the light at Neptune's orbit and the light at ours, as well as the difference between the light at our orbit and that at Mercury's, depends quite as much upon the density of the ethereal medium as upon the difference of the distance through it.

3. That the ethereal medium is so rare as almost to preclude all idea of diminution in the solar light even at a distance so remote from the sun as Neptune's orbit, and even if the medium had been uniform.

4. That the ethereal medium is not uniform,—being incomparably least rare in the regions nearest to the sun.

5. That the diminution of light which takes place in this medium at Neptune's orbit is only one-ninth more than the diminution which takes place at ours; instead of being 900 times greater, which it would have been if the medium were uniform.

6. That this diminution is so small as to render it physically impossible that light at Neptune's orbit should be sensibly different from light at ours;—*a fortiori*, therefore, that light at any other planet's orbit should be sensibly different from light at ours.

7. That Neptune's greater distance from the sun does not make the light at the base of his atmosphere 900 times less than that at the base of ours; nor Mercury's greater proximity to the sun make the light at the base of his atmo-

sphere seven times greater than that at the base of ours.

8. That the solar heat and light enjoyed by the inhabitants of Neptune and of all the superior planets, are quite as great as what we enjoy upon the earth, and may not impossibly be even somewhat greater. Also, that the light and heat to which the inhabitants of Mercury and Venus have access by their position in the system, are no greater than we enjoy here, and that there is no physical cause connected with their proximity to the sun why they may not have even less of this light and heat than we have.

That those serious and profound men of science who never had a doubt of God's moral government in all the planets of our system, nor even in all the planets of all the stars, should have paid little attention to the exact amount of light and heat which He has provided for Neptune, or for any other planet, while so much still lay unexplored before them, and should have merely adopted (as far as any of them have adopted it) the popular expres-

sion of this matter without canvass or scrutiny, cannot surprise us. It is perfectly excusable and intelligible that they should have done so. There is in this nothing that can even seem to be "irreverent,"—nothing that can even seem to imply that want of respect for evidence, or that want of faith in science, for which, and especially for disseminating which, we are all of us most justly held responsible to one another. Other and more urgent investigations than the so obvious and long acknowledged analogy between our planets naturally engrossed those brilliant powers of research, the slightest glance from which would have long since anticipated these humble pages in detecting a blunder so superficial as that now pointed out. But we cannot say that it is thus with the author of the Essay "Of the Plurality of Worlds." Far otherwise. Even that writer himself acknowledges that his doctrine carries the appearance of irreverence—the appearance of want of faith in science—the appearance of want of respect for that sort of evidence upon which all our deepest hopes are founded. And in this he is not mistaken. He does not even succeed in removing

the impression. The very eagerness with which he grasps at what he might have so easily discovered to be an error, betrays him. He is therefore in a very different position from those who held that error without injustice to others. In their case it was but a problem postponed. In his it was an error employed,—and employed, unwittingly it may be, against a great and cherished cause. On this account he alone is responsible for this and the other similar errors upon which he has attempted to establish his strange views. That any one of competent information and ability, as this Essayist appears to be, should have lightly ventured to assert that there was most probably no moral government in any other world of our system except this, and to assert that analogy in this case, however strong, was to be considered of no weight at all, upon the plea that there was either too little or too much heat and light in the other planets for moral agents—that things are a great deal too heavy in one of them, and that some are composed wholly of water;—that he should have done this without that thorough investigation of the facts which we have now shown to have

been omitted upon his part, cannot fail to surprise even his greatest admirers, and must long remain a monument of the "boldness," the "guessing," and the levity with which learning unhappily—it must be unconsciously—has too often arraigned the providence of our Great Architect.

The only further optical explanation which it remains for us to offer is that connected with the size of the sun's disc at Neptune. It is there seen under an angle of little more than sixty seconds. Here it subtends an angle of thirty minutes. Its diameter is therefore nearly thirty times—its area nearly 900 times—smaller at Neptune than on the Earth;—so that while to the inhabitants of Neptune the sun presents a disc about half an inch wide, the width of the disc that we see is about fifteen or sixteen inches. It will naturally be asked what effect this will have upon the light. Will it not render it at least these thirty times less? An instant's attention to the laws of optics will convince us that it does not;—that however much the disc may be diminished—even if it be lost sight of altogether—it will emit all the light of

the sun's larger disc, except only to whatever extent this light has been diminished by the media through which it has to pass. The mistake upon this point seems to have arisen from the fact that in a uniform medium the light and the visual area of an illuminated surface decrease, both of them, equally (viz., inversely as the square of the distance), but from very different causes.

To understand this matter thoroughly, let us suppose for a moment that the solar disc is seen through a perfect vacuum, except in as far as the atmospheres of the planets are concerned. The consequence is that none of the light is intercepted in the spaces between the sun and the planets. Whatever diminution takes place (if any) must be otherwise accounted for.

Now, it is a law in optics that the amount of light received from any surface depends (apart from the mass of the medium) upon the number of physical luminous points in that surface, and upon the intrinsic brightness of each point. If the whole disc is illuminated, the number of these points depends upon the actual extent of the surface; and it is evident that however much

the rays issuing from these points may subsequently converge, or concentrate, — provided they remain of the same number and of the same brightness,—their mere convergence can only have the effect of compressing or condensing them into a smaller compass, just as occurs in the case of a burning glass, and cannot by any possibility produce a diminution either of the number or of the brightness of the rays proceeding from the illuminated surface. In fact, when it is said that the rays converge, this only means that they become more dense, more compact than they were before, and not, as is commonly thought, either fewer in number or individually less bright; for what is there to render them so? If they had to pass through a medium, a diminution of the brightness of each ray would take place, according to the length and density of this medium, while their number would be undiminished; but in the supposed case of a complete vacuum, there is nothing to diminish the brightness, any more than the number of the rays. The reader will thus see how the effect of the medium has been unconsciously transferred by learned men, from the

medium to which it properly belongs, to the distance to which it does not belong at all; or, at least, how it has been attributed by them inadvertently to both, whereas such an effect as the diminution of brightness could only result from the medium, as diminution of size only from the distance. This distinction must be very carefully made if we care to attain to the truth upon this subject.

The consequence of the foregoing facts is, that light emitted from the sun's disc (*i. e.* as seen when we look at the disc) is less dazzling at Mercury, and at Neptune a great deal more dazzling than it is here. As Neptune is thirty times farther from the sun than we are, and Mercury nearly three times nearer, the sun's diameter appears (as we have said) thirty times less at Neptune than here, and at Mercury nearly three times greater; and as circles are to one another as the squares of their diameters, his disc or visual area at Neptune is 900 times less, and at Mercury nearly seven times greater than here. The effect of which upon the closeness or density of the rays is to make them that much closer and more dazzling at Neptune,

and that much less close at Mercury, — that much therefore less dazzling than here. The sun's light also we can see from this is not, upon his surface, that intolerable thing we suppose; nor is it of as little consequence to us as we imagine that the stars are at such a distance from us as to present no disc. The vast lengths of the excessively thin ethereal medium which their rays have to traverse, is all that there is to produce that reduction of their light—so necessary where they are so many, and which reason teaches us that this thin medium never could effect without these vast lengths of it. And all that is said here of light is true of heat also. When to these reflections, we add the fact, already so fully explained, that, although the space between the sun and the confines of our system is not a perfect vacuum, it is very nearly so, the ethereal medium, even if it had been uniform, being too thin to effect any appreciable diminution in the brightness of each solar ray in its passage out to Neptune, and that the solar rays are all there condensed into $\frac{1}{900}$ of the space in which we have them in our disc (or, in other words, in which we see them

from our planet)—it follows that the solar disc in order to be looked at from Neptune's surface, requires thirty times as effective a shade to save the eyes as we need here for the same purpose, and that in Mercury one seven times less effective than ours would be sufficient.

We perceive, then, that at Neptune the sun's disc is not, as with us, a pretty large circle, but as it were a mere point of such brilliant light as to render it unendurable to look directly at it without a suitable apparatus, and that this point tracing in about five of our hours, a radiant line from east to west, pours into each square foot of the outer strata of that planet's atmosphere the same amount of light and heat as we receive into each corresponding portion of the external surface of our atmosphere, allowance being made (as already observed) for the very small—the imperceptible diminution effected by the ethereal medium between us and Neptune. And if it should seem to any one an extraordinary result that all the daylight and heat that we are conscious of, and accustomed to associate with the idea of a larger disc, should in Neptune proceed from a mere luminous point (such

as Venus or Jupiter appears to us) he need only reflect upon the dimensions of our own solar disc. Is not that also out of all proportion to the effect that attends it. The whole hemisphere of 180 degrees is lighted up by a spot equal to $\frac{1}{130.000}$ of the whole, filling it all up with heat and light. We need no more than this to show us that the size of the disc—the visible size of the sun—has nothing to do with the amount of illumination we receive, and that we might have it as well from a disc of half an inch diameter as from one of fifteen inches, provided there be the same solar force to be diffused, and the same atmospheric force to diffuse it.

As to the look of the thing—the strange effect of a solar disc so bright that the inhabitants cannot look in its direction of the heavens, and that few except the astronomers ever care to see it—in this also it is not impossible that we allow ourselves to imagine a greater difference than there really is. Even we are not so constantly occupied as might be supposed with our solar disc. It is in the minds of all of us a thing of very different importance to the light and heat that we derive from it. How many of us never

look at it or think of it for days, for weeks, and for whole months together. There is little to remind most of us whether it is through a point or a circle that we have our light and heat. How often we are completely unable to point out its position, whether to the right or to the left of us, before us or behind us—how little we are ever conscious even of the presence—to say nothing of the diameter—of that disc, or of the extent to which it has been diminished from the sun's own enormous diameter. And when we think of this last matter, that a diameter of more than 800,000 miles is reduced for the inhabitants of one planet to one of about fifteen or sixteen inches, we must see that the difference is exceedingly little when for the inhabitants of another planet the reduction is brought down to a diameter of little more than half an inch. If a disc of *fifteen inches* represent sufficiently a diameter of 800,000 miles, why should it seem strange that a disc of *half an inch* should do so? Both discs are, in fact, mere points. The great matter, however, is to know that a diminished disc is no index either of diminished light or of diminished heat, nor of any other thing than merely of increased distance.

Thus then we see with scientific certainty that neither on account of deficient or excessive light, nor on account of deficient or excessive heat, nor with regard to the density of the materials, nor with regard to the force of gravity upon the surfaces is there the slightest pretext for supposing that all the planets of our system are not inhabited by intellectual creatures with animal bodies like ourselves,—moral beings who know and love their Great Maker, and who wait, like the rest of His creation, upon His providence and upon His care.

THE END.

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